

# ***LI-840A***

***CO<sub>2</sub>/H<sub>2</sub>O GAS ANALYZER***

**Instruction Manual**

***LI-COR***<sup>®</sup>

Biosciences



***LI-840A***  
***CO<sub>2</sub>/H<sub>2</sub>O Analyzer***

**Instruction Manual**

***LI-COR***<sup>®</sup>

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Federal Communications Commission

Radio Frequency Interference Statement

**WARNING:** This equipment generates, uses, and can radiate radio frequency energy and if not installed in accordance with the instruction manual, may cause interference to radio communications. It has been tested and found to comply with the limits for a Class A computing device pursuant to Subpart J of Part 15 of FCC rules, which are designed to provide a reasonable protection against such interference when operated in a commercial environment. Operation of this equipment in a residential area is likely to cause interference in which case the user, at his own expense, will be required to take whatever measures may be required to correct the interference.



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## Warranty

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# 1

## General Description

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### What's What

This procedure should be followed if you have just taken delivery of your LI-840A. Check the packing list to verify that you have received everything that was ordered and that you have also received the following items:

- **RS-232 Cable** - (Part #392-04993), used to connect the LI-840A to your computer. This cable is a null modem (cross-over) type cable; a straight through type cable will not work with the LI-840A. Appendix C shows the pin assignments for the DB-9 connector on the LI-840A front panel. An RS-232-to-USB converter is provided as well (Part # 6400-27)
- **Data Communications Software** - This Windows® 7, 8/8.1, and 10 compatible software is used for communication between the LI-840A and a computer. The software is provided on CD. A complete description of this software can be found in "*Operation*" on page 3-1.

## Section 1

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- **Standard Spare Parts Kit (9980-021)** - This kit contains replacement parts for the LI-840A. As you become familiar with the analyzer you will learn which items to keep close at hand and which items can be stored away. The spare parts kit contains these items:

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<b>Description</b>	<b>Qty.</b>	<b>LI-COR Part No.</b>
Polyurethane Mounting Feet	4	234-02268
Mounting Screws	4	149-02610
Terminal Block	1	331-05273
Bev-a-line Tubing	12'	222-01824
Gelman Air Filter	2	9967-008
Quick Connect Unions	2	300-03123
Rapid Tube Fitting Nut	2	9861-036
2A Fuse	2	439-03952
Cleaning Kit, includes:	1	9980-013
5" Cleaning Swabs	5	610-05315
O-Rings	4	192-00226
Pre-formed Optical Bench Tubing	4	6580-010

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## Features

The LI-840A is an economical, high performance, non-dispersive infrared gas analyzer designed to be used for a wide variety of applications. Some of the LI-840A's important features include:

- A 14 cm (5.5") optical bench is used to obtain a CO<sub>2</sub> measurement range of 0-20,000 ppm (parts per million, or  $\mu\text{mol/mol}$ ) and an H<sub>2</sub>O measurement range of 0-80 mmol/mol.
- The optical bench is fully serviceable by the user; cleaning the optical bench is a simple process, and does not affect the instrument's factory calibration.
- Simple Windows® software provides for easy user calibration and data output.

## Precautions

- The optical bench is maintained at a constant temperature of about 50 °C. Avoid direct exposure to sunlight or extremely high temperatures that may elevate the temperature inside the LI-840A case.
- The optical source is sensitive to vibration, and can be damaged by strong vibrations or jarring. Do not drop the LI-840A or expose it to severe mechanical shock.

- Do not use abrasive cleansers when cleaning the optical bench, as damage to the gold plating may result. Instructions for cleaning the optical bench can be found in Section 5.
- Always filter air entering the LI-840A. Two Gelman filter assemblies (p/n 9967-008) are included in the spares kit.

## Getting Started Tutorial

The following section briefly covers the basic steps you might follow to set up the LI-840A to collect and record data. Many of these steps are described in greater detail throughout this manual.

# 1

### **Install the PC Communications Software.**

This software is used to set the zero and span of the LI-840A and set up data communication and data transfer parameters for viewing and logging data. Installation instructions can be found in *"Installing the PC Communication Software on Your Computer" on page 3-1.*

# 2

### **Determine your jumper settings for high and low alarm output, if required.**

There are 2 jumpers inside the LI-840A case (on the main circuit board), which toggle the high and low alarm output between 0-5V (TTL levels) and an open drain condition.

The default jumper positions are set for 0-5V output for both high and low alarms. This alarm configuration is suitable for logic devices such as dataloggers. To use the high and/or low alarms to

operate a relay switch, the jumpers should be reconfigured for open drain output. See "Alarms" on page 2-1, for a description of how to change the alarm jumper settings.

If the default jumper positions are suitable for your application, or if you do not intend to use the alarms, proceed to Step 3.

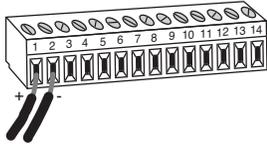
### 3

#### Connect a power source to the LI-840A

The LI-840A requires an input voltage of 12-30 VDC. The power supply must be able to source a maximum current drain of 1.2A (at 12 VDC). After the instrument has warmed up it will draw about 0.3A (at 12 VDC) with the heaters on.

Bare wire leads are connected to the terminal strip at positions 1 and 2. Connect the positive lead (usually red) to position #1 (12-30VDC), and the negative lead to position #2 (GND).

**NOTE:** Pull straight out on the face of the terminal strip to remove it; this can make it easier to connect the wires.



# 4

### **Connect the RS-232 cable.**

Connect one end of the serial cable to the 9-pin Serial I/O port on the LI-840A front panel, and the other end to a serial port on your computer. If you want to interface to a device with a 25-pin serial port, a 9-pin to 25-pin adapter must be used; a gender changer may be required in some cases. Tighten the two screws on the ends of the serial cable.

# 5

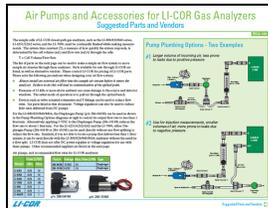
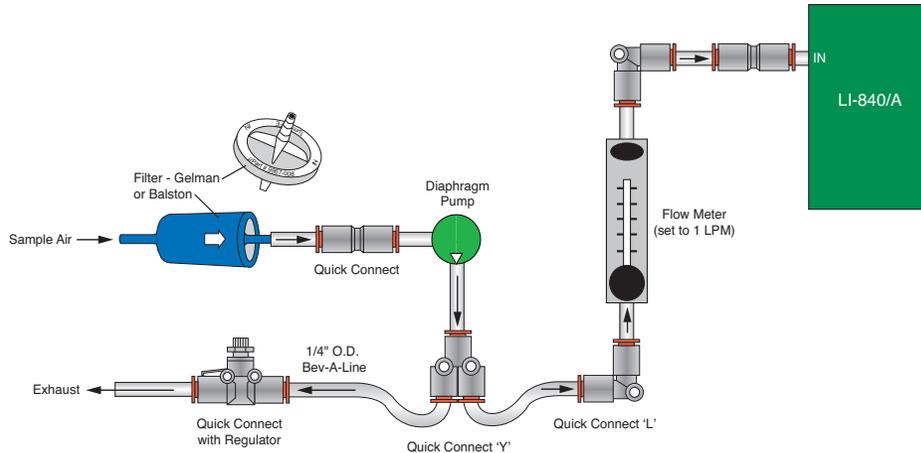
### **Connect other output device(s) if desired.**

Output devices such as dataloggers and relay switches for high and low alarms are connected via the terminal strip. A complete description of the terminals can be found in Section 3, Using the Terminal Strip.

# 6

### **Connect an air pump and external power source.**

The LI-840A sample cell must be continually flushed while making measurements, which requires an external air pump that supplies a flow rate of between 0.25 and 1.0 liters per minute. LI-COR offers a Diaphragm Pump under part number 286-04198 that is suitable for use with the LI-840A. One pump plumbing option is shown below.



**NOTE:** More information about plumbing options and parts available from LI-COR can be found in Application Note #IRG4-105, entitled ‘Air Pumps and Accessories for LI-COR Gas Analyzers - Suggested Parts and Vendors’, which can be downloaded from [www.licor.com/env/support](http://www.licor.com/env/support).

# 7

## Connect the input air stream and external filter.

Remove the nut from the **FLOW IN** fitting and connect a short (12" or so) piece of Bev-a-line tubing (from the spares kit) . Tighten the nut. Place a Geman filter (also from the spares kit) in the sample airstream before it enters the **FLOW IN** port on the LI-840A. A user-supplied pump is required to force air through the LI-840A.

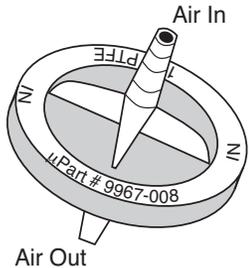
**IMPORTANT:** Always install the external air filter before operating the LI-840A. Insert filter into the input airstream before it enters the LI-840A. Failure to do this will lead to contamination of the optical path.

When using the LI-840A for applications where sample air is particularly dirty, you may consider stacking two filters in series. For maintenance, replace the filter furthest upstream from the analyzer with the filter closest to the analyzer and replace the filter closest to the analyzer with a new filter.

*Install the new filter(s) with the blue lettering facing away from the **FLOW IN** port.*

The air inlet and outlet ports should be covered with the dust caps provided or attached to an air line when the instrument is not in use. This will prevent dust from entering the instrument downstream from the filters where it can enter the optical path.

Replacement Gelman Acro 50 filters can be obtained from LI-COR (part #9967-008).



## 8

### **Start the PC Communications Software.**

Click on the program icon to start the application. The Main window appears. Select **Connect** from the File menu. Choose the serial port to which the LI-840A is connected, and the data output interval. Click the **Connect** button. If the analyzer is connected properly, data will appear in the main window.

## 9

### **Configure the analyzer.**

Select **Settings** from the View menu. The Settings window appears. Choose a value for signal averaging (the Filter field), between 0 and 20 seconds. Set values for high and low alarms and corresponding dead bands, if desired. See Section 2 for a complete description of the alarms. If you are using an output device to collect data, choose the value to be output at DAC 1 and/or DAC 2. Make sure the Enable Heater and Pressure Compensation buttons are enabled (checked), and click **OK**.

# 10

## Set the analyzer zero.

**NOTE:** The LI-840A is calibrated at the factory before shipping. It is recommended, however, that you verify the calibration by connecting a gas with known concentration and reading the displayed value. If the instrument needs to be calibrated, follow the steps below.

Connect a dry, CO<sub>2</sub>-free gas to the input air stream. Select **Calibration** from the View menu. Click on the **Zero** tab. Click the **Zero CO<sub>2</sub>**. Wait up to 15 minutes for any water vapor to clear from the optical cell, then click the **Zero H<sub>2</sub>O** button. After several seconds, a message will appear that indicates the IRGA is zeroed.

# 11

## Set the analyzer span.

Connect a span gas with known concentration of CO<sub>2</sub> to the input air stream. Choose a span gas that will be below or close to the highest reading expected. Select the **Span** tab. Enter the value of the span gas in ppm. Click on **Span CO<sub>2</sub>**. A message will appear indicating when the span calibration is completed.

Connect an airstream with a known water vapor concentration (such as may be generated by the LI-610 Portable Dew Point Generator). Enter the dew point value of the H<sub>2</sub>O span gas, in degrees C, and click on **Span H<sub>2</sub>O**.

Connect a second span gas with a known concentration of CO<sub>2</sub> to the input air stream. If the reading is not within 1% of the expected value, perform a second span: use a span gas with a concentration that is higher than the highest expected reading. Under the **Span 2** tab enter the 2<sup>nd</sup> span gas concentration and click **Span CO<sub>2</sub>**.

Check the H<sub>2</sub>O reading with a water vapor concentration that is higher than that used to set the H<sub>2</sub>O span. If the reading is outside the acceptable range, perform a secondary H<sub>2</sub>O span. Click **Close**.

# 12

### **Set up the logging parameters.**

Select **Options** from the Logging menu. Choose the File Header(s) to be output with the data, the values to be logged, the field delimiter, and log frequency. Click **OK**. Choose **Start** from the Logging menu. Enter a file name for the data file. Click **Save**.

# 13

### **Set up the charting parameters, if desired.**

Select **Charting** from the View menu. Enter the value to be plotted, the Y-Axis min and max values, X-Axis max, and time units to be displayed on each plot. Click **Start** to begin recording data. Graphs with data will appear in the window and data will be logged to the file designated in Step 11 above.

# 14

### **Choose Stop from the Logging menu to stop recording when you are done collecting data.**

# 2

## Power On

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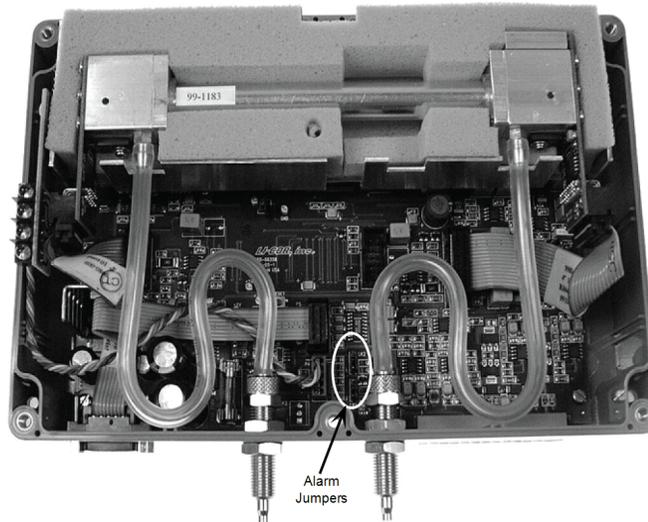
### Power On

The LI-840A can be connected to a constant source of AC power using a transformer that provides 12-30VDC (14W maximum) to the LI-840A. If the LI-840A is powered with a voltage below 10.5 volts, the analyzer will not power up, and the Low Battery LED on the top panel will illuminate. The LI-840A will continue to operate with a low battery; there will, however, be a corresponding reduction in performance.

### Alarms

The LI-840A is equipped with high and low alarms, which can be configured as open collector or 0-5V output (TTL levels) using jumpers on the main PC board (Figure 2-1 on the next page). The default configuration is 0-5V output. Figure 2-2 on page 2-3 shows the position of the jumpers for each of the two alarm conditions.

The alarms can be used for either CO<sub>2</sub> or H<sub>2</sub>O concentrations; only one can be chosen at a time, however.



*Figure 2-1. Location of alarm jumpers LK1 and LK2.*

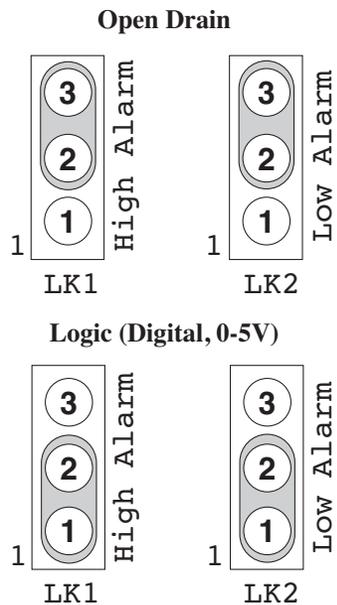
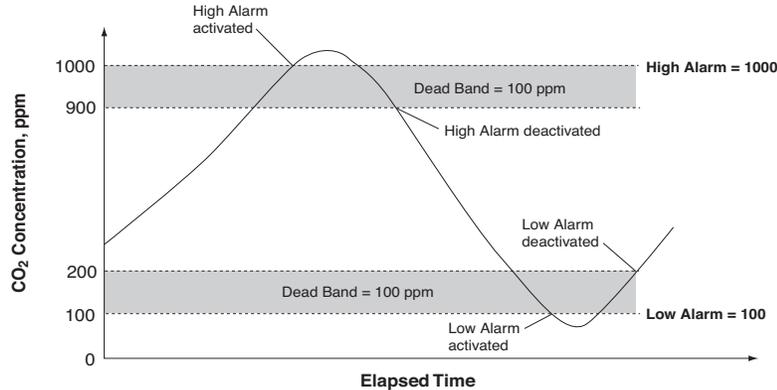


Figure 2-2. Position of jumpers for open drain and 0-5V output.

## Section 2

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In addition, a "dead band" value can be set in software for both high and low alarms. To understand how the alarms and dead band values work, look at the diagram below.

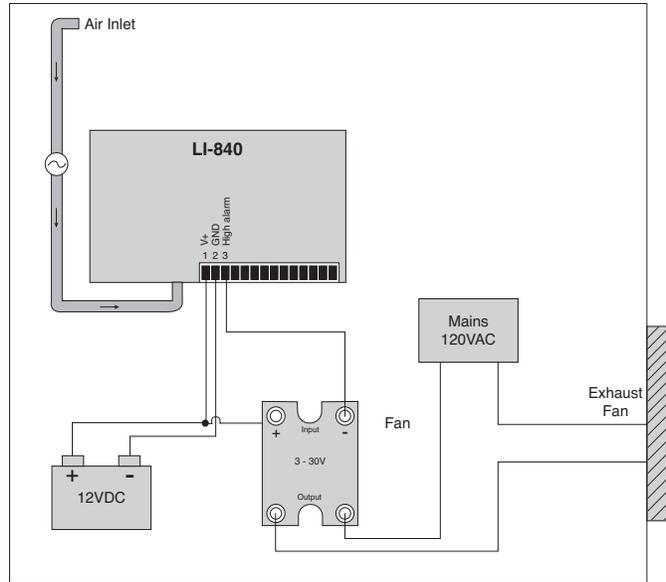


In this chart, the low and high alarm values are set to 100 ppm and 1000 ppm, respectively. The dead band value in both alarms is set to 100 ppm. When the CO<sub>2</sub> concentration reaches 1000 ppm, the high alarm is activated, and remains active until the concentration drops below 900 ppm. When the CO<sub>2</sub> concentration falls below 100 ppm, the low alarm is activated, and remains active until the concentration rises above 200 ppm. Your choice for the dead band value(s) depends on your application and the fluctuation in CO<sub>2</sub> concentrations over time.

**Note:** Increasing the signal average value in software (see Settings Window; Options; Filter in Section 3) can help reduce fluctuations in readings.

Alarm LEDs can be viewed on the top panel of the LI-840A. Terminals 3 and 5 on the terminal strip are also connected to the High and Low alarms, respectively. This is useful for connecting an audible alarm, for example, or a relay switch to operate another device that will raise or lower the CO<sub>2</sub> concentration to the desired level. The schematic diagram below shows how the high alarm could be connected to a relay switch that triggers an exhaust fan in a greenhouse environment. These relays could also be used to trigger devices such as automatic dialers, alarms, pumps, and valves in industrial and other environments.

## Section 2



A list of suppliers of electronic relay switches can be found in Appendix D.

**NOTE:** Consult your local electrical codes before wiring, and/or have a professional electrician wire your application.

# 3

## Operation

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### Installing the PC Communication Software on Your Computer



The software application is shipped on CD. It requires that your computer have an RS-232 serial (COM) interface, and Windows® XP/Vista/7. The program runs on any PC compatible computer.

An installation menu will start when you insert the CD into your CD-ROM drive. Select *Install Software* from the menu and follow the instructions. If installation does not start, select **Run** from the Windows *Start* menu, and select the LI840Setup.exe file on the CD. When the software has finished the installation procedure, a program icon will be placed in the Programs menu.

**NOTE:** To remove the software, go to the Control Panel and select *Add/Remove Programs* (XP) or *Uninstall a program* (Vista/7). Choose LI840 from the list of programs and click the Add/Remove button. If your computer has the older LI840 software, be sure to use the correct program when configuring the LI-840A.

### Setting the Communication Parameters

LI-840A communication parameters are set automatically when the program is run.

### Cabling

The serial cable (null modem) included has 9-pin connectors on both ends; either end plugs into the 9-pin connector (Serial I/O) on the front panel of the LI-840A. Use this cable to interface with your computer's 9-pin serial port. If you want to interface to a computer with a 25-pin serial port, a 9-pin to 25-pin adapter must be used. To connect to a computer with a USB port, a 9-pin serial to USB adapter must be used.

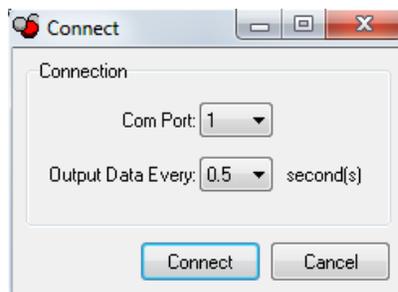
### RS-232 Output

Data from the LI-840A can be transferred to a computer for analysis, printing or storage using the RS-232 interface. The LI-840A RS-232 port is configured as Data Terminal Equipment (DTE) with no hardware handshaking, and is bi-directional, meaning information can be transferred both into and out of the LI-840A.

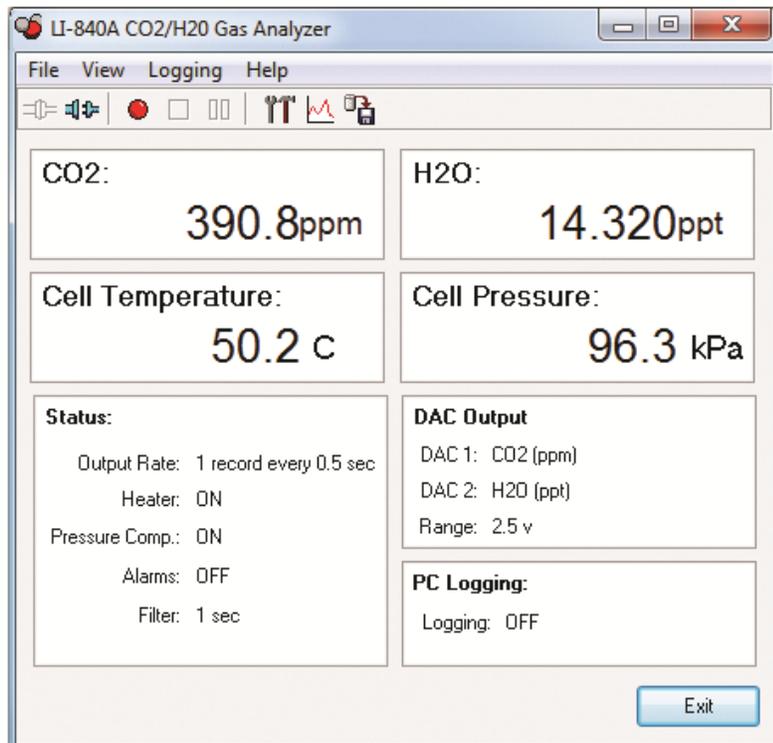
The application software that comes with the LI-840A is used to view data and configure the LI-840A from a PC.

## Initial Setup

Click on the LI-840A program icon to start the program. The LI-840A Main Window appears. Select **Connect** from the File menu, or click on the connect icon on the toolbar, beneath the File menu. You are asked to select the serial port to which the LI-840A is connected, and the output interval at which data are output (0.5 to 20 seconds, in 0.5 second increments).



Choose a COM port and the output interval and click **Connect**. If the instrument is connected properly, data will begin to appear in the Main window (below):



The Main Window displays the CO<sub>2</sub> concentration (ppm) and H<sub>2</sub>O concentration (°C or mmol/mol), cell temperature and pressure, and the status of various LI-840A parameters. There are also three menus used to configure the LI-840A, perform zero and span calibrations, and set up the parameters for recording data.

Note that you can view H<sub>2</sub>O concentrations in units of degrees C or mmol/mol. To change the units in the Main window, go to the View menu and toggle the **H2O in ppt** menu item on and off. Alternatively, you can click on the H<sub>2</sub>O units being displayed in the Main window to change the display.

The LI-840A parameters displayed in the Main window are as follows:

<b>Parameter</b>	<b>Description</b>
Cell Temperature	Temperature (°C) in the LI-840A optical cell. This value should remain near 50 °C when the heater is turned ON.
Cell Pressure	Barometric pressure (kPa) measured in the LI-840A optical cell. This value can be used to correct measurements for the effects of atmospheric pressure.
Output Rate	Displays data output rate chosen at connection.
Heater	Shows status of heater (ON/OFF), which is used to maintain the optical cell at a constant 50 °C. The heater is turned ON/OFF in the Settings window.

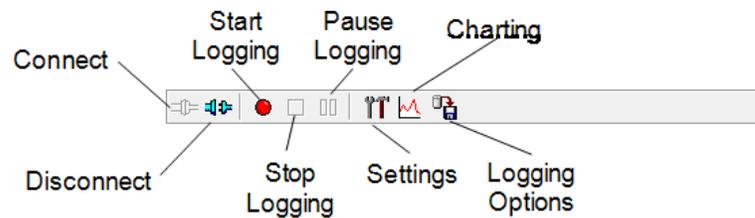
## Section 3

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<b>Parameter</b>	<b>Description</b>
Pressure Comp.	Shows whether pressure compensation is ON/OFF. When ON, measurements are corrected for the effects of pressure fluctuations on gas density and band broadening.
Alarms	Shows status of High and Low alarms, whose values are set in the Settings window. Alarms are enabled (ON), or disabled (OFF).
Filter	Shows the current value for software signal averaging, set in the Settings window. The filter can be set from 0 (no signal averaging) to 20 seconds.
DAC Output	Displays source channels for DAC1 and DAC2, and the voltage output range (0-2.5V or 0-5V).
PC Logging	Shows "Off" if data are not being logged to a file, or "Logging" when data are being logged to a file.

## Using the Toolbar

The toolbar in the Main window contains shortcuts for some of the commonly used menu items:



### Settings Window - Setting Operational Parameters

The Settings window contains parameters related to initial setup of the LI-840A, including signal filtering, high and low alarm setup, heater and pressure compensation options, and DAC output sources. Choose **Settings** from the View menu (or click on the toolbar icon) to open the Settings window:

The screenshot shows a 'Settings' dialog box with the following sections and annotations:

- Alarms:**
  - Enable Alarms
  - Source:  CO<sub>2</sub> /  H<sub>2</sub>O
  - High Alarm: 600 ppm
  - High Dead Band: 50 ppm
  - Low Alarm: 400 ppm
  - Low Dead Band: 10 ppm
- Options:**
  - Enable Heater
  - Pressure Compensation
  - Filter: 5 Sec
- DAC Output:**
  - Range:  0.0v - 2.5v /  0.0v - 5.0v
  - DAC 1 Source: H<sub>2</sub>O ppt
  - 0v: [ ]
  - 5v: [ ]
  - DAC 2 Source: CO<sub>2</sub>
  - 0v: 300
  - 5v: 700

Annotations on the left side:

- Disable the alarms here, set high and low alarm values, and high and low
- Use these radio buttons to choose CO<sub>2</sub> or H<sub>2</sub>O as the alarm source.
- The heater should be enabled to maintain the optical bench at a constant 50 °C.
- Pressure compensation should be enabled to compensate for gas density changes caused by variations in pressure.
- Software signal filtering is available from 0-20 seconds.

Annotations on the right side:

- Select the DAC output range with these radio buttons.
- DAC output sources. Choose data to be output to DAC 1 and/or DAC 2.
- CO<sub>2</sub> range output by fully scalable DACs. Select the desired concentration range that voltage outputs should correspond with. In this example, 0v represents 300 ppm and 5v is 700 ppm CO<sub>2</sub>. The measurement range for CO<sub>2</sub> with the LI-840A is 0-20,000 ppm.

### Options

#### *Enable Heater*

The Heater should be enabled to maintain the optical bench at a constant 50 °C.

#### *Pressure Compensation*

Enable the Pressure Compensation check box to automatically correct gas concentration values for changes in cell pressure. In most cases this should be turned on; disabling this feature means that no pressure correction is desired in the gas concentration calculations, which can lead to erroneous measurements.

#### *Filter*

Shows the current value for software signal averaging. The filter can be set from 0 (no signal averaging) to 20 seconds. Note that increasing the filter decreases instrument noise but reduces the response time.

### DAC Output

Analyzer output for up to 2 values (none, CO<sub>2</sub>, H<sub>2</sub>O mmol/mol, H<sub>2</sub>O °C, Cell Temperature, or Cell Pressure) can be recorded by connecting a logging device to the terminal strip on the front of the analyzer. Output is linear, and is selectable at 0-5V or 0-2.5V. Choose the full-scale voltage output range and the source for DAC 1 and/or DAC 2. You can also choose a range over which to scale the output(s); you can achieve better resolution by scaling the output(s) over a narrower range when appropriate.

The DACs in the LI-840A are bipolar, and will go slightly negative ( $\sim -0.100\text{V}$ ). This can happen, for example, if the cell becomes contaminated or from small random perturbations when the  $\text{CO}_2$  concentration is near zero. See Section 5, Cleaning the Optical Bench for instructions on cleaning the cell should it become contaminated.

Voltage output is measured by attaching the positive lead from the logging device to terminal 9 (V Out 1), or terminal 7 (V Out 2) on the LI-840A terminal strip. Connect the negative lead to position 10 (GND), or position 8 (GND).

The  $\text{CO}_2$  or  $\text{H}_2\text{O}$  concentration can be calculated from the DAC output voltage as follows:

$$\text{Concentration} = (X_F - X_Z) \frac{V}{V_{\max}} + X_Z \quad 3-1$$

where  $V$  is the measured voltage,  $X_F$  is the full scale value for  $\text{CO}_2$  or  $\text{H}_2\text{O}$  output (entered in the Settings Window as the 2.5 or 5V value, up to 20,000 ppm for  $\text{CO}_2$ ),  $X_Z$  is the zero value entered, and  $V_{\max}$  is the full scale DAC output voltage selected (5V or 2.5V).

**Example:** The DAC output range selected is 0-5V ( $V_{\max}$ ), the zero  $\text{CO}_2$  value entered is 0 ppm ( $X_Z$ ), the full scale  $\text{CO}_2$  value entered is 2000 ppm ( $X_F$ ), and the measured output voltage ( $V$ ) is 2.9V. To calculate the  $\text{CO}_2$  concentration from Equation above,

$$\begin{aligned} \text{CO}_2 &= (2000) \frac{2.9}{5} + 0 && 3-2 \\ &= 1160 \text{ ppm.} \end{aligned}$$

## Section 3

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**Example:** The DAC output range selected is 0-5V ( $V_{\max}$ ), the zero CO<sub>2</sub> value entered is 1000 ppm ( $X_Z$ ), the full scale CO<sub>2</sub> value entered is 2000 ppm ( $X_F$ ), and the measured output voltage (V) is 2.9V. To calculate the CO<sub>2</sub> concentration from Equation above,

$$\begin{aligned} CO_2 &= (2000 - 1000) \frac{2.9}{5} + 1000 && 3-3 \\ &= 1580 \text{ ppm.} \end{aligned}$$

The H<sub>2</sub>O concentration (mmol/mol) can be calculated from the DAC output voltage as follows:

$$H_2O = (X_F - X_Z) \frac{V}{V_{\max}} + X_Z \quad 3-4$$

where V is the measured voltage,  $X_F$  is the full scale value for H<sub>2</sub>O output (entered in the Settings Window as the 2.5 or 5V value, up to 80 parts per thousand),  $X_Z$  is the zero value entered, and  $V_{\max}$  is the full scale DAC output voltage selected (5V or 2.5V).

**Example:** The DAC output range selected is 0-5V ( $V_{\max}$ ), the zero H<sub>2</sub>O value entered is 0 ppm ( $X_Z$ ), the full scale H<sub>2</sub>O value entered is 80 mmol/mol ( $X_F$ ), and the measured output voltage (V) is 2.9V. To calculate the H<sub>2</sub>O concentration from Equation 3-4 above,

$$\begin{aligned} H_2O &= (80 - 0) \frac{2.9}{5} + 0 && 3-5 \\ &= 46.4 \text{ mmol/mol.} \end{aligned}$$

**Example:** The DAC output range selected is 0-5V ( $V_{\max}$ ), the zero H<sub>2</sub>O value entered is 10 mmol/mol ( $X_Z$ ), the full scale H<sub>2</sub>O value entered is 60 mmol/mol ( $X_F$ ), and the measured output voltage (V) is 2.9V. To calculate the H<sub>2</sub>O concentration from Equation 3-4 above,

$$\begin{aligned} H_2O &= (60 - 10) \frac{2.9}{5} + 10 && 3-6 \\ &= 39.0 \text{ mmol/mol.} \end{aligned}$$

### *Converting Voltage Output to Cell Temperature*

Cell temperature can be calculated from the DAC output voltage as follows:

$$T (^{\circ}C) = (X_F - X_Z) \frac{V}{V_{\max}} + X_Z \quad 3-7$$

where V is the measured voltage,  $X_F$  is the full scale value for temperature output (entered in the Settings Window as the 2.5 or 5V value, up to 100 °C),  $X_Z$  is the zero value entered, and  $V_{\max}$  is the full scale DAC output voltage selected (5V or 2.5V).

### *Converting Voltage Output to Cell Pressure*

Cell pressure can be calculated from the DAC output voltage as follows:

$$Pressure (kPa) = (X_F - X_Z) \frac{V}{V_{\max}} + X_Z \quad 3-8$$

## Section 3

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where V is the measured voltage,  $X_F$  is the full scale value for cell pressure output (entered in the Settings Window as the 2.5 or 5V value, up to 115 kPa),  $X_Z$  is the zero value entered, and  $V_{max}$  is the full scale DAC output voltage selected (5V or 2.5V).

### *Converting Current Output to ppm CO<sub>2</sub> or mmol/mol H<sub>2</sub>O*

Current output can be measured by connecting the positive input of the data logging device to positions 11 or 13 (4-20 mA 2 or 4-20 mA 1), and the negative input to position 12 or 14 (GND). The current output at positions 11 and 13 is non-isolated, and is rated to drive a 250 ohm load.

Note that these channels mirror their respective voltage output channels; current output channel 1 uses the variable chosen for voltage output 1, and current output channel 2 uses the variable chosen for voltage output 2. Similarly, a voltage output of 0 volts corresponds to a current output of 4 mA, and when the voltage outputs are at full scale (2.5 or 5 V), the current output will be 20 mA.

To convert current output (I) to CO<sub>2</sub> or H<sub>2</sub>O concentration in your computer or other output device, the following equation can be used:

$$\text{Concentration} = (X_F - X_Z) \left( \frac{I-4}{16} \right) + X_Z \quad 3-9$$

where I is the measured current,  $X_F$  is the full scale value for CO<sub>2</sub> or H<sub>2</sub>O concentration output (entered in the Settings Window as the 2.5 or 5V full scale value, up to 20,000 ppm for CO<sub>2</sub>), and  $X_Z$  is the zero value entered.

---

**Example:** The zero CO<sub>2</sub> value entered is 0 ppm (X<sub>Z</sub>), the full scale CO<sub>2</sub> value entered is 2000 ppm (X<sub>F</sub>), and the measured current output (I) is 16.25 mA. To convert to ppm CO<sub>2</sub>:

$$CO_2 = (2000) \left( \frac{16.25 - 4}{16} \right) + 0 \quad 3-10$$
$$= 1531.25 \text{ ppm.}$$

### CO<sub>2</sub> Span Range

The span range entry field determines the maximum CO<sub>2</sub> range over which the LI-840A will make measurements. The factory calibration range for the LI-840A is 0-20,000 ppm. Note that there is a benefit to selecting a narrower range if that range is adequate for your experiment. The narrower range provides better resolution in terms of the digital-to-analog converter (DAC). For example, if you choose a range of 0-1500 ppm, each step of the DAC is able to resolve twice as many data points as compared to the 0-3000 ppm range, which results in better resolution.

### Alarms

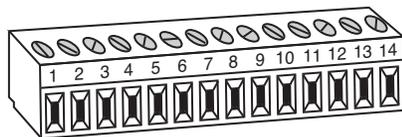
Allows you to enable/disable the alarms, and enter high, low, and dead band values. A complete discussion can be found in Section 2, Alarms.

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### Using the Terminal Strip

The terminal strip is located on the front panel of the LI-840A. To connect the wires, insert the bare wire end into the appropriate terminal and tighten the screw above that terminal using the small flat head screwdriver in the spare parts kit. The front face of the terminal strip can be removed to aid in connecting the wires by pulling straight out on the face.



The terminal positions are as follows, reading from left to right:

Terminal	Label	Description
1	12-30 VDC	Voltage In, 12-30 VDC
2	GND	Ground
3	High Alarm	High Alarm
4	GND	Ground
5	Low Alarm	Low Alarm
6	GND	Ground
7	V OUT 2	Voltage output channel 2
8	GND	Ground

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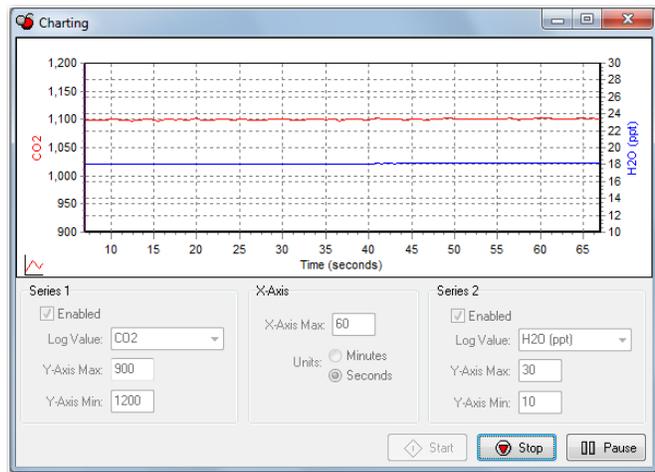
<b>Terminal</b>	<b>Label</b>	<b>Description</b>
9	V OUT 1	Voltage output channel 1
10	GND	Ground
11	4-20 mA 2	Current output channel 2
12	GND	Ground
13	4-20 mA 1	Current output channel 1
14	GND	Ground

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## Section 3

### Charting Window

Select **Charting** from the View menu to open the Charting window (below). This is the window in which you can set up the parameters for plotting your data. Two charts can be plotted simultaneously, using Y axes on either side of the chart.



#### Series 1

The Series 1 options are used to plot a chart with the Y axis on the left side of the chart. Choose the value to be logged and set the maximum and minimum values for the Y axis.

## **Series 2**

The Series 2 options are used to plot a chart with the Y axis on the right side of the chart. Choose the value to be logged and set the maximum and minimum values for the Y axis.

### **X-Axis Max**

Sets the maximum value for the X axis (Time). The units for the X axis can be seconds or minutes.

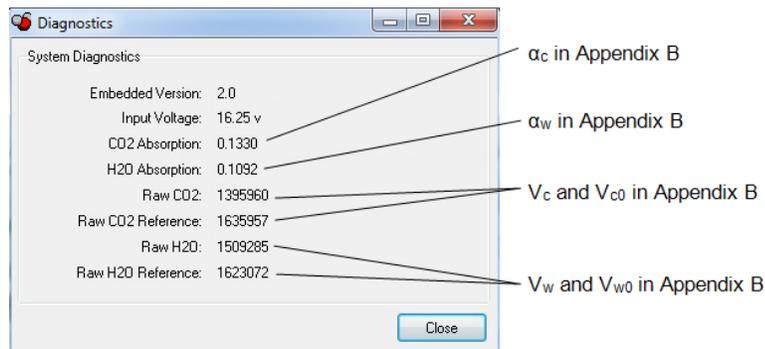
Press **Start** at any time to view the chart layout and begin displaying data. Note that you must press **Stop** to make changes to the chart parameters, and then press **Start** again to resume data display.

## Section 3

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### Diagnostic Window

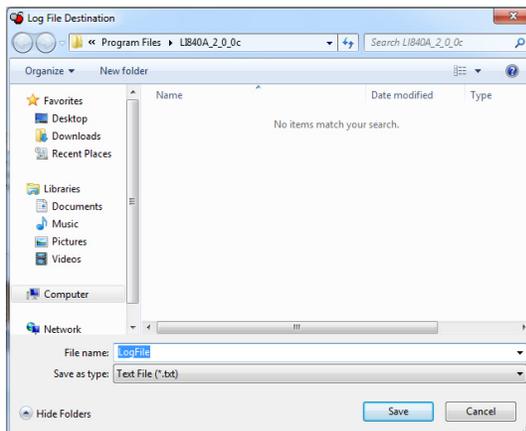
Select **Diagnostics** from the View menu to open the Diagnostics window (below). This window displays the current LI-840A internal software version number, the input voltage, and raw absorption values.



## Logging Data

### Start Logging

Opens the Log File Destination dialog, where you enter a file name for the data file. The file extension .txt is added automatically.



### Stop Logging

Stops data logging.

### Pause Logging

Pauses logging of data until **Start** is chosen from the Logging menu again, or the Start button on the toolbar is pressed.

### Options

Opens the Logging Options window, where you can configure the data output options.



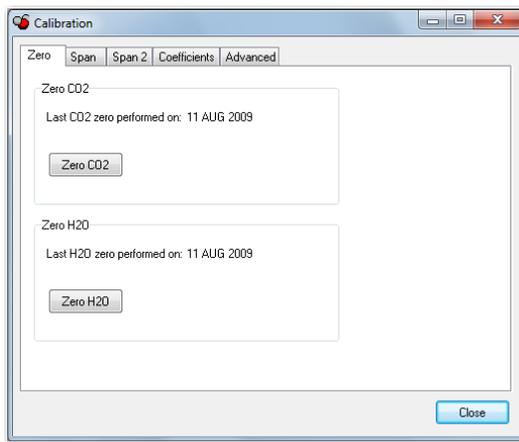
## Section 3

As configured above, the data output would appear similar to that shown below.

```
"2009-10-28 at 17:20"  
Time(H:M:S) CO2(ppm) H2O(pppt) H2O(C) Cell_Temperature(C) Cell_Pressure(kPa) CO2_Absorption H2O_Absorption  
17:20:00 1110.25 18.91 15.96 52.19 96.28 0.1546 0.1031  
17:20:01 1111.11 18.89 15.95 52.22 96.30 0.1546 0.1030  
17:20:02 1108.04 18.90 15.96 52.22 96.30 0.1544 0.1031  
17:20:03 1108.03 18.89 15.95 52.22 96.30 0.1544 0.1031  
17:20:04 1108.52 18.90 15.96 52.22 96.30 0.1544 0.1031  
17:20:05 1109.97 18.90 15.96 52.22 96.30 0.1545 0.1031  
17:20:06 1109.64 18.92 15.97 52.22 96.29 0.1545 0.1032  
17:20:07 1108.60 18.91 15.97 52.19 96.29 0.1544 0.1031  
17:20:08 1109.82 18.91 15.97 52.19 96.30 0.1545 0.1031  
17:20:09 1109.67 18.92 15.97 52.22 96.28 0.1545 0.1032  
17:20:10 1108.83 18.92 15.97 52.22 96.30 0.1544 0.1031  
17:20:11 1110.16 18.93 15.99 52.22 96.30 0.1545 0.1032  
17:20:12 1107.31 18.93 15.98 52.22 96.28 0.1543 0.1032  
17:20:13 1110.40 18.91 15.97 52.22 96.31 0.1546 0.1031  
17:20:14 1111.08 18.94 15.99 52.22 96.27 0.1546 0.1032  
17:20:15 1109.57 18.93 15.98 52.19 96.28 0.1545 0.1032
```

## Calibration Window - Setting the Zero and Span

Select **Calibration** from the View menu to open the Calibration window. This is the area in which you set the zero and spans of the LI-840A.



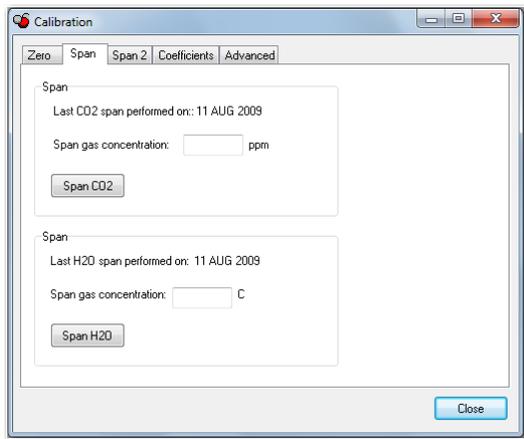
It is recommended that you perform the zero calibrations first, followed by the span calibrations. To zero, flow a dry, CO<sub>2</sub>-free gas through the LI-840A and make sure the optical cell is completely purged. Press the **Zero CO<sub>2</sub>** button under the Zero tab.

The display will show ZERO, and the text in the Calibration window is greyed out. The zero will be set electronically, and the current date will be entered in the "Last CO<sub>2</sub> zero performed on:" field

## Section 3

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when completed. Repeat for the H<sub>2</sub>O channel. *Note: Purge the cell with the H<sub>2</sub>O zero gas for up to 15 minutes before zeroing H<sub>2</sub>O. Water vapor molecules are “sticky” and it may take up to 15 minutes to reach equilibrium in the optical cell.*



To span, connect a span gas of known CO<sub>2</sub> concentration to the input air stream. Make sure the cell is purged. Under the Span tab, enter the value of the span gas and click on **Span CO<sub>2</sub>**.

The display will show SPAN, for several seconds and the text in the Calibration window will be greyed out. The span will be set electronically, and the current date will be entered in the "Last CO<sub>2</sub> span performed on:" field when completed. *Note: Ensure that the CO<sub>2</sub> standards are accurate, as this will determine the overall accuracy of the LI-840A.*

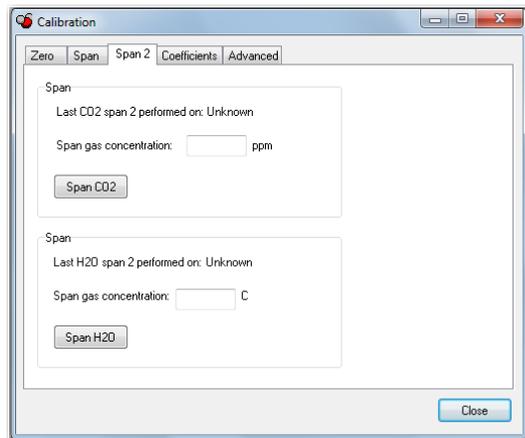
Repeat for the H<sub>2</sub>O channel using an airstream of known dew point. *Note: Purge the cell with the H<sub>2</sub>O span gas for up to 15 minutes before spanning H<sub>2</sub>O. The LI-610 Portable Dew Point Generator is capable of providing an airstream with a known water vapor concentration.*

### **Two Point Span (Span 2 Tab)**

Suppose you have two non-zero calibration gasses (e.g. CO<sub>2</sub> at 300 ppm and 1500 ppm), and you use one of them (say, 1500 ppm) to set the span. If you then flow the other gas through the LI-840A, you would expect it to read within 1% of the expected value (in our example, 300 ±3 ppm). If it does not, you can adjust the calibration for this by performing a Secondary Span, by entering the span gas concentration and clicking the **Span CO<sub>2</sub>** (Span 2 tab). After that, the 300 ppm tank should read 300, and the 1500 tank should still read 1500. This can also be performed with H<sub>2</sub>O if needed.

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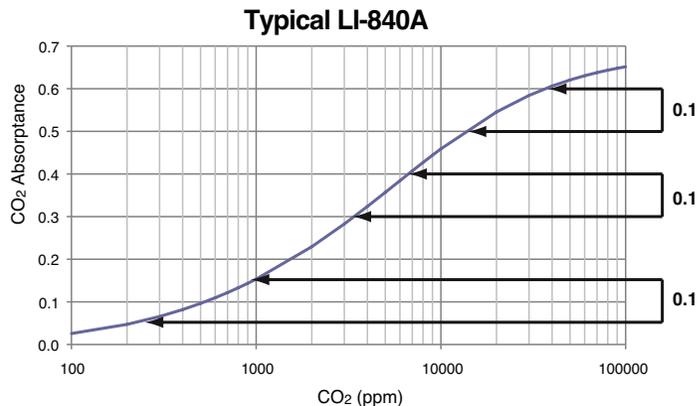
In the LI-840A version 2.0 and above, the span value is a linear function of absorbance, and thus has two parameters, a slope and an offset (see Appendix B for details). Normal span setting adjusts the offset and leaves the slope alone. Setting the secondary span adjusts the slope, then adjusts the offset value for the new slope value. The slope and offset values can be viewed on the Advanced page (described below). Span offset values (CO<sub>2</sub> Span and H<sub>2</sub>O Span) are typically  $1.0 \pm 0.1$ . Span slope values (CO<sub>2</sub> Span 2 and H<sub>2</sub>O Span 2) are typically  $0 \pm 0.1$ . When they are exactly 0, then slope is a constant, and not a function of absorbance.

The CO<sub>2</sub> span slope value is first determined at the factory by setting the span at 200 ppm, and doing an secondary span close to 20000 ppm. This value should remain valid for some time. Things

that are likely to make it change include changing the source and/or changing the detector, a dirty optical cell, and possibly even taking the optical bench apart for cleaning.

### Considerations for performing a secondary span:

- Zero first.
- After zeroing, do a (normal) span.
- The span and secondary span concentrations should be as far apart as possible and they should bracket the concentration range of interest to you. (e.g. 200 and 20000, or 300 and 1500, etc.). “Far apart” means in absorbance, not concentration. We recommend absorbance differences of at least 0.1 when choosing concentrations for setting span and secondary span (see the figure below).

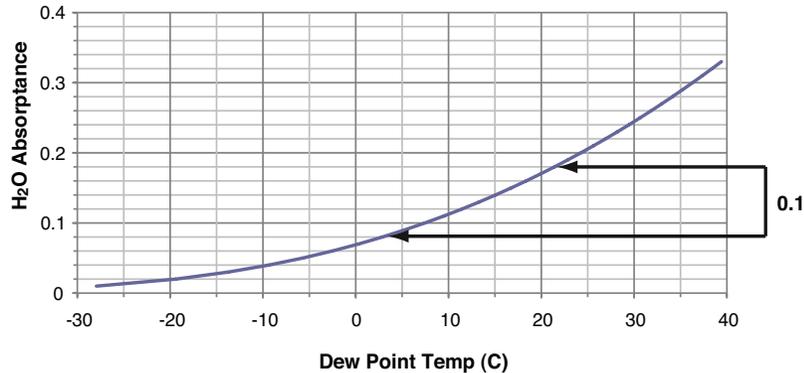


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For CO<sub>2</sub>, The difference in absorbance between 200 and 1000 ppm is typically about 0.1. There is also a 0.1 absorbance difference between 3500 and 7000 ppm, and between 15,000 ppm and 40,000 ppm. For H<sub>2</sub>O, it is a little harder to get a 0.1 absorbance difference. If you want to do a secondary span at room temperature, for example, the two span values would have to be 5 °C or less, and 22 °C, for example.

**Typical LI-840A**



You can do multiple secondary spans after a normal span. For example, span at 200, then do a secondary span at 3000. Then (assuming you didn't like the result for some reason), you can do another secondary span at 2000 ppm. As long as the secondary span is well away (in absorbance) from the previous normal span, it is OK to do as many consecutive secondary spans at various concentrations as you'd like.

## Coefficients Page

The LI-840A uses a double rectangular hyperbola for the CO<sub>2</sub> calibration, and a third order polynomial for H<sub>2</sub>O calibration. The Coefficients page displays these factory-determined calibration coefficients, as well as those for band broadening and cross sensitivity, and coefficients for the internal pressure transducer. These coefficients are fixed at the factory.

The screenshot shows a software window titled "Calibration" with a "Coefficients" tab selected. The window is divided into four main sections: CO2, H2O, Pressure, and Corrections. Each section contains input fields for calibration coefficients. The CO2 section has four fields labeled A1 through A4. The H2O section has three fields labeled A1 through A3. The Pressure section has two fields labeled A0 and A1. The Corrections section has two fields labeled Band Broadening and Cross Sensitivity. At the bottom of the window, there are three buttons: "Send Coefficients", "Cancel", and "Close".

Section	Parameter	Value
CO2	A1	1.0992600E1
	A2	5.3642897E1
	A3	1.0401098E2
	A4	1.0242500E2
H2O	A1	2.8746101E-1
	A2	2.8455300
	A3	-1.6282000
Pressure	A0	
	A1	
Corrections	Band Broadening	1.4500000
	Cross Sensitivity	-3.0000002E-3

The calibration coefficients are unique to each instrument, and may be found on the calibration sheet shipped from the factory. In most cases you will not want to alter any of these values.

A description of the band broadening can be found in Appendix B, Equation Summary.

### Advanced Page

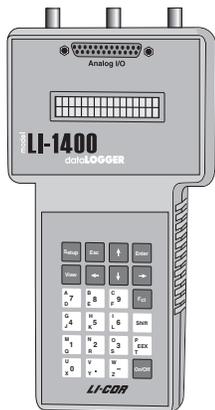
The calibration constants for CO<sub>2</sub> and H<sub>2</sub>O zero and span calibrations are found on the Advanced calibration page. These constants are stored to a file on the computer by clicking on **Save to Defaults**. Click **Load Defaults** to restore the values in this window using the file on the PC. If new constants are entered in this window, click **Send Constants** to send the values to the LI-840A for implementation.

In most cases you should not change the values in this window; see Appendix B, *Equation Summary* for a description of the terms used in this window.

The screenshot shows a software window titled "Calibration" with a standard Windows-style title bar (minimize, maximize, close buttons). The window contains a tabbed interface with four tabs: "Zero", "Span", "Span 2", and "Advanced". The "Advanced" tab is currently selected. Inside the "Advanced" tab, there is a section titled "Calibration Constants" which contains several input fields and two buttons. The input fields are arranged in two columns. The first column contains "CO2 Zero:" with the value "8.8867092E-1", "CO2 Span:" with the value "1.0114669", "CO2 Span 2:" (empty), "H2O Zero:" with the value "1.0032711", "H2O Span:" with the value "9.9719476E-1", and "H2O Span 2:" (empty). The second column contains two buttons: "Load Defaults" and "Save to Defaults". Below the "Calibration Constants" section, there are two buttons: "Send Constants" and "Cancel". At the bottom right of the window, there is a "Close" button.

Parameter	Value
CO2 Zero:	8.8867092E-1
CO2 Span:	1.0114669
CO2 Span 2:	
H2O Zero:	1.0032711
H2O Span:	9.9719476E-1
H2O Span 2:	

## Connection the LI-840A to the LI-1400 Datalogger



The following example shows how you can connect the LI-840A to a datalogging device such as the LI-COR Model LI-1400 DataLogger to collect analog data and convert to meaningful CO<sub>2</sub> and/or H<sub>2</sub>O values. As mentioned earlier, voltage output from the LI-840A is linear; converting analog data into ppm CO<sub>2</sub> or mmol/mol H<sub>2</sub>O simply requires multiplying the raw mV output by a conversion factor, which is dependent upon the selected voltage output range, and the maximum CO<sub>2</sub> or H<sub>2</sub>O resolution available (set in software between 0-20,000 ppm). In general, the conversion takes the form:

$$\text{Concentration} = (X_F - X_Z) \frac{V}{V_{\max}} + X_Z \quad 3-11$$

where V is the measured voltage, X<sub>F</sub> is the full scale value for CO<sub>2</sub> or H<sub>2</sub>O output (entered in the Settings Window as the 2.5 or 5V value, up to 20,000 ppm for CO<sub>2</sub>), X<sub>Z</sub> is the zero value entered, and V<sub>max</sub> is the full scale DAC output voltage selected (5V or 2.5V).

For example, if the voltage output is set for 0-5V (V<sub>max</sub>), the zero CO<sub>2</sub> value entered is 0 ppm (X<sub>Z</sub>) and scaled CO<sub>2</sub> range is 2000 ppm (X<sub>F</sub>), and the measured voltage output is 2.9V, the equation would take the form:

$$\begin{aligned} CO_2 &= (2000) \frac{2.9}{5} + 0 \\ &= 1160 \text{ ppm.} \end{aligned} \quad 3-12$$

This general equation can be converted into simple multipliers, based on the two available voltage output ranges and the CO<sub>2</sub> (maximum 20,000 ppm) or H<sub>2</sub>O (maximum 100% RH) range. These can be any value, depending on what is chosen for the 0V and the full scale 2.5V and 5V DAC output values. Each multiplier can then be entered in the data logging device to convert raw voltage to CO<sub>2</sub> or H<sub>2</sub>O values. Table 3-1 lists some examples of values for this multiplier; simply choose your DAC output range in the second row, and then select the LI-840A CO<sub>2</sub> range in the first column (the full scale value minus the zero value); follow across to find the appropriate multiplier. Note that this table assumes that the zero value ( $X_Z$ ) is zero; if it is not zero, the offset will need to be added onto the final result.

**Table 3-1.** Multipliers for Converting Voltage Output to CO<sub>2</sub> Readings (no offset).

	DAC Output Range	
	0-5V	0-2.5V
$X_F - X_Z$	Multiplier (ppm/Volts)	
1000 ppm	200	400
2000 ppm	400	800
5000 ppm	1000	2000
20000 ppm	4000	8000

To calculate multipliers:

$$\mathbf{Multiplier} = \frac{\mathbf{X_F - X_Z}}{\mathbf{V_{max}}} \qquad 3-13$$

where  $X_F$  is the full scale value for  $\text{CO}_2$  or  $\text{H}_2\text{O}$  output,  $X_Z$  is the zero or offset value entered, and  $V_{\text{max}}$  is the full scale DAC output voltage selected (5V or 2.5V).

The LI-1400 can be used to monitor voltage signals up to 2.5 volts with 76 microvolt resolution in real time and convert them into meaningful engineering units shown on the display. Alternatively, the LI-1400 can be configured to automatically log these data over extended periods of time and later transfer the results to a computer for further analysis.

Access to the voltage channels requires the 1400-301 Terminal block. Voltage channels are designated by the letter “V” and sequentially numbered V1-4. The lead from LI-840A terminal #7 or #9 should be attached to one of the LI-1400 terminals labeled V1, V2, V3, or V4, while the lead from terminal #8 or #10 should be attached to one of the LI-1400 terminals labeled ↓ (ground). See the LI-1400 manual for further details.

The following example shows how you can set up the LI-1400 Data Logger to collect raw voltage output from the LI-840A and convert to  $\text{CO}_2$  values.

1. Set the voltage output of the LI-840A for 2.5V output and specify the zero and maximum values for  $\text{CO}_2$  as described in Section 3, *Analog Output*.

2. In the LI-1400, configure V1 channel as *General* for CO<sub>2</sub>.
3. Enter a description, such as CO<sub>2</sub>.
4. Set Math = *Poly(nomial)* and press *Enter*.
5. Set description as desired, *a0* = the offset (for scaled measurements), *a1* = multiplier from Table 3-1 on page 3-35 (or Equation 3-13), and *a2-a5* = 0. When finished, press *Esc* to return to the main configuration list.
6. Set *Operator* = *none*.
7. Enter a *Label* such as *ppm* for the units.
8. Set *Average=1 sec* or as desired. CO<sub>2</sub> will now be displayed on channel V1.

To log CO<sub>2</sub> automatically, follow the remaining steps:

9. Set *Log Routine* to the desired log routine.
10. Set *Calc=Mean*.
11. To capture the minimum and maximum CO<sub>2</sub> values, set *MinMax* accordingly.
12. *TCoeff* has no effect when *Calc=Mean*. It is used only when integrating.



# 4

## Theory of Operation

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### System Overview

The LI-840A CO<sub>2</sub>/H<sub>2</sub>O Gas Analyzer is an absolute, non-dispersive, infrared (NDIR) gas analyzer based upon a single path, dual wavelength, infrared detection system. The CO<sub>2</sub> and H<sub>2</sub>O measurements are a function of the absorption of IR energy as it travels through the optical path. Concentration measurements are based on the difference ratio in the IR absorption between a reference and sample signal. Reference and sample channels measure infrared gas absorption in a single path through the use of narrow band optical filters with appropriately selected bands. The CO<sub>2</sub> sample channel uses an optical filter centered at 4.26 micrometers, corresponding to an absorption band for CO<sub>2</sub>. The reference channel for CO<sub>2</sub> has an optical filter centered at 3.95 micrometers, which has no absorption due to CO<sub>2</sub>. The H<sub>2</sub>O sample channel uses an optical filter centered at 2.595 micrometers, corresponding to an absorption band of H<sub>2</sub>O. The reference channel for H<sub>2</sub>O has an optical filter centered at 2.35 micrometers, which is a non-absorbing region for H<sub>2</sub>O.

The instrument uses digital signal processing techniques to determine the temperature and pressure corrected CO<sub>2</sub> concentration based on the optical bench signals using a ratiometric computation. The data are passed through a double rectangular hyperbola (CO<sub>2</sub>) or 3rd order polynomial (H<sub>2</sub>O) that performs linearization of the detector signal to a mole fraction in air given in μmol CO<sub>2</sub> per mole of air (ppm), and mmol H<sub>2</sub>O per mole of air (mmol/mol).

Data output is provided in a digital format through an RS-232 interface that supports connection to an external computer. The instrument comes with a Windows® XP/Vista/7 compatible application for instrument configuration, control, data collection and display. Analog signals are available through a terminal block for collection by a data logger or similar means.

### Optical Bench System

The LI-840A CO<sub>2</sub>/H<sub>2</sub>O Gas Analyzer optical path is a thermostatically controlled IR detection system. The optical bench operation is based upon a broad band IR source and a pyroelectric detector. The source is mounted in a parabolic reflector to collimate the light and increase energy throughput down the optical path to the detector. The reflector and optical path are gold plated to further increase energy transmission. The detectors are pyroelectric devices that operate based on thermal energy received. The narrow band optical filters allow only the wavebands of interest to illuminate the detector, allowing for the determination of CO<sub>2</sub> and H<sub>2</sub>O concentrations in the presence of other infrared absorbing gases.

The detectors respond to thermal energy, so it is necessary to precisely regulate the detectors' temperature. This allows for differentiation of thermal gradient noise from the received signals from the optical path. The detection system is shown in Figure 4-1 on the facing page.

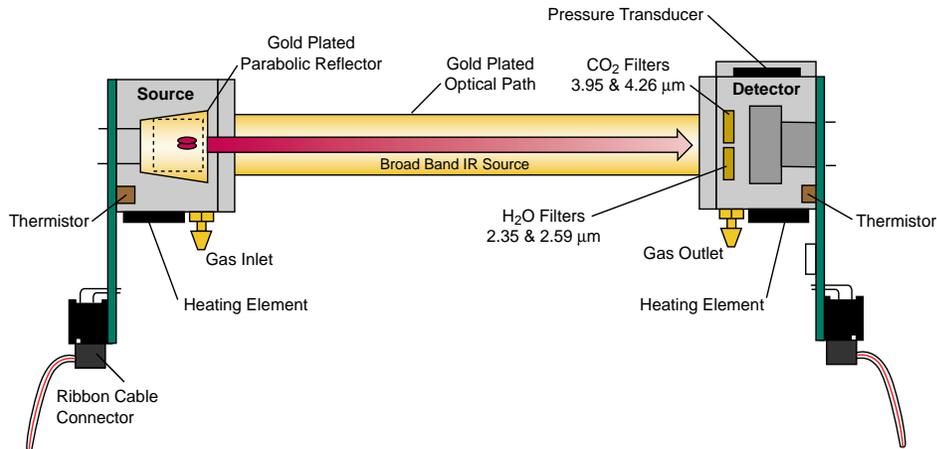


Figure 4-1. Schematic diagram of the LI-840A optical bench.

The optical bench has a thermostat that maintains a constant operating temperature of 50 °C. A feedback loop is used to regulate the optical bench temperature. As shown in Figure 4-1, two thermistors, located in the source and detector housings, measure the present temperature. The thermistors are monitored as part of the control loop to determine corrections necessary in the thermal balance. Two heating elements are the sources of thermal energy into the source and detector housing. The optical path is in mechanical contact with the source and detector housing and thereby achieves thermal equilibrium.

The bench requires approximately 10 minutes to achieve the specified thermal temperature. A longer period of approximately 20 minutes is required to bring the performance of the detection system to within 1 to 2% of reading. As shown in Figure 4-1 on the previous page, the detector housing has a pressure transducer integrated into the housing design. Part of the CO<sub>2</sub> concentration calculation depends on the pressure observed in the optical path, measured with an in-line pressure transducer. Many parameters can affect the pressure and thus the concentration reading. The processing center in the analyzer reads the pressure reading as part of its data collection task and uses this information in the concentration calculation. The gas flow enters the source housing, passes down the optical path and exits at the detector housing. The maximum flow rate for the analyzer is approximately 1 liter/min.

Another key parameter in the concentration calculation is the gas temperature in the optical path. It is assumed in the analyzer operation that the gas temperature will equilibrate to the optical bench temperature (50 °C) by the time it enters the optical path. Since the instrument performs temperature and pressure corrections as part of the concentration calculation, this assumption is very important. To cause the sample air to equilibrate to the optical bench temperature, an airflow pattern is created with sufficient eddy currents to cause thermal equilibration.

The optical bench is mounted in a foam enclosure to accomplish two purposes. The first is to assist in maintaining the controlled thermal environment required for the optical bench as described above. The second function of the foam enclosure is to protect the optical bench from mechanical shock and vibration that might damage the mechanically sensitive components. The foam enclosure is supported by an optical bench “tray” which is in turn attached to the main circuit board (PCB). The optical bench is mechanically de-coupled from the case by creating the s-bend in the Bev-a-line tubing from the external fittings to the optical bench gas inlet and outlet connectors. The electronic interface to the source and detector is achieved through printed circuit boards mounted directly to the source and detector housings, respectively. The PCBs connect the main PCB to the source and detector PCBs via a ribbon cable. This achieves the mechanical isolation desired for the optical bench.

A 14 cm (5.5") optical bench provides a CO<sub>2</sub> measurement range of 0 – 20,000 µmol/mol (ppm), and an H<sub>2</sub>O measurement range of 0-80 mmol/mol.



# 5

## Maintenance

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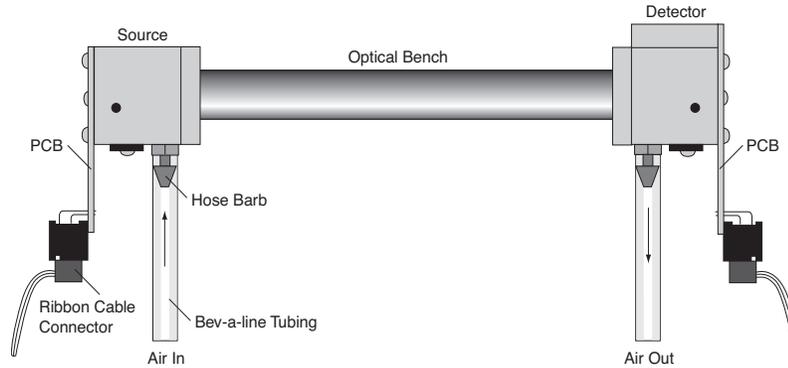
### Cleaning the Optical Bench

The LI-840A optical bench can be removed and cleaned if necessary. If the optical path becomes dirty it may become difficult to span the analyzer. Excessive zero drift may also be observed if the optical path becomes dirty. Follow these steps to clean the optical bench:

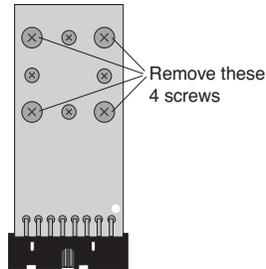
- 1.** Turn the LI-840A off. Remove the six screws on the LI-840A top panel and remove the cover. Note that these screws are not molded into the case and may fall out.
- 2.** Unscrew the tube retaining nuts on the inner air port fittings. Remove the tubing from both air ports. Leave the tubing connected to the source and detector housings.
- 3.** There are ribbon cables connected to the circuit boards on the source and detector housings, as shown below. Pull straight out on the connector that is attached to each ribbon cable. The optical bench can now be removed from the foam casing.

## Section 5

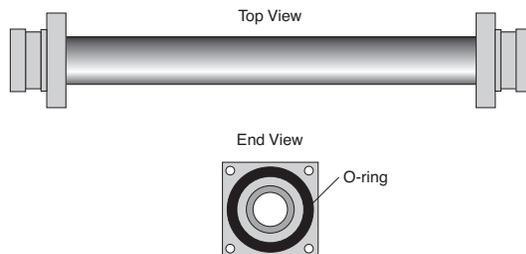
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4. There are four screws on the source and detector circuit boards that must be removed. Remove the four screws in the corners of the boards, as shown below (they are slightly larger than the other four screws). Do not remove the remaining four screws.



5. The source and detector housings (with attached circuit boards) can now be removed. The bench will appear as shown below. It is a good practice to replace the O-rings when cleaning or replacing the optical path.



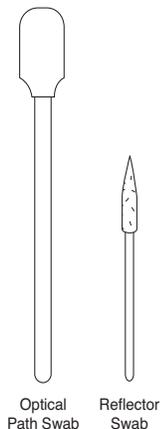
6. There are a number of swabs in the spare parts kit. Dip one end of the swab into a 50:50 ethanol/water solution and carefully swab both ends of the optical bench, until there is no more visible residue. A mild solution of dish washing type soap and water will also work. **Do not use abrasive cleansers, as they can irreparably damage the gold plating on the optical bench.**
7. Use a reflector swab and carefully swab the gold-plated concave surface of the source housing, if necessary.
8. If you need to clean out the hose barbs or replace the tubing connected to the source and detector housings, use a small pair of diagonal cutters to remove the tubing from the hose barbs. Use the cutters to pinch the tubing parallel to the hose barb axis, and then pivot the cutters over the hose barb tip; the tubing will pull off of the hose barb. **Be very careful not to cut the tubing**

## Section 5

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*or scratch the hose barb with the cutters, as subsequent tubing connections may leak if the hose barb is damaged.*

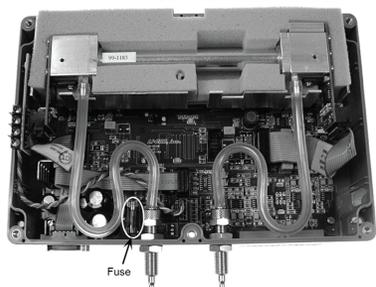
- 9.** Let the optical bench dry. Re-assemble the bench, making sure the O-rings are in place on both ends of the bench. Note that the orientation of the cylinder is not important; either end can be inserted into the source or detector housing.
- 10.** Re-assemble the LI-840A case. Make sure that the foam insulation on the inside top cover is positioned over the optical bench; it is required for thermal stability.
- 11.** Perform zero, span, and secondary span calibrations as described in *"Calibration Window - Setting the Zero and Span"* on page 3-25.



## Changing the Fuse

The LI-840A power supply is protected by a 2A 250V, 5 × 20 mm fast-blow type fuse located inside the case. If the battery fails to power the LI-840A, and will not light the Power LED on the top panel, check to see if the fuse has blown.

To check the fuse, remove the six screws on the top of the LI-840A. The fuse is located on the main circuit board, near the **Flow In** port, as shown below. Replacement fuses (part #439-03952, in the spares kit) plug into the fuse holder; no soldering is required. Replace the fuse and reassemble the LI-840A case.



### Note on Infrared Source Replacement

The infrared source in the LI-840A is rated for more than 18,000 hours of life. Should the source fail, a replacement can be obtained from LI-COR Biosciences. The source can be replaced in the field; however, it should be noted that changing a source has the potential of degrading the accuracy specification for CO<sub>2</sub> to as much as 3% of reading. The H<sub>2</sub>O channel should remain within the published specification.

If the source fails, the instrument can be returned to LI-COR Biosciences for replacement and factory recalibration. This will ensure that the accuracy stays within the factory specifications. Alternatively, if you have two span gasses, you can adjust the calibration yourself. See *"Two Point Span (Span 2 Tab)" on page 3-27*.

# A

## Specifications

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CO<sub>2</sub><sup>1</sup>

**Measurement Range:** 0-20,000 ppm

**Accuracy:** Better than 1.5% of reading

**Calibration Drift**

**Zero Drift:** <0.15 ppm/°C

**Span Drift:** < 0.03 %/°C

**Total Drift at 370 ppm:** <0.4 ppm/°C

**RMS Noise at 370 ppm with 1 sec signal filtering:** <1 ppm

**Sensitivity to water vapor:** < 0.1 ppm CO<sub>2</sub>/mmol/mol H<sub>2</sub>O

H<sub>2</sub>O

**Measurement Range:** 0-60 mmol/mol

**Accuracy:** Better than 1.5% of reading

**Calibration Drift**

**Drift<sup>2</sup> at 0 mmol/mol:** <0.003 mmol/mol/°C

**Span Drift<sup>3</sup> at 10 mmol/mol:** <0.03 %/°C

**Total Drift<sup>4</sup> at 10 mmol/mol:** <0.009 mmol/mol/°C

**RMS Noise at 10 mmol/mol with 1 sec signal filtering:** <0.01 mmol/mol

**Sensitivity to CO<sub>2</sub>:** <0.0001 mmol/mol H<sub>2</sub>O/ppm CO<sub>2</sub>

**Measurement Principle:** Non-Dispersive Infrared

**Traceability:** Traceable gases to WMO standards for CO<sub>2</sub>. NIST traceable LI-610 Portable Dew Point Generator for H<sub>2</sub>O

**Pressure Compensation Range:** 15 kPa-115 kPa

**Maximum Gas Flow Rate:** 1 liter/min

**Output Signals:** Two analog voltage (0-2.5V or 0-5V) and two current (4-20mA)

**Digital:** TTL (0-5V) or Open Collector

**DAC Resolution:** 14-bits across user-specified range

**Source Life:** ~18,000 Hours

**Power Requirements:** Input Voltage 12-30 VDC

1.2A @ 12V (14W) maximum during warm-up with heaters on

0.3A @ 12V (3.6W) average after warm-up with heaters on

**Operating Temperature Range:** -20°C to +45°C

**Relative Humidity Range:** 0 to 95% RH, Non-Condensing

**Dimensions:** 8.75" × 6" × 3" (22.23 × 15.25 × 7.62 cm)

**Weight:** 2.2 lbs (1 kg)

**Internal Optical Cell Volume:** 14.5 mL

<sup>1</sup>Specifications subject to change without notice

<sup>2</sup>Zero drift is the change with temperature at 0 concentration.

<sup>3</sup>Span drift is the residual error after re-zeroing following a temperature change.

<sup>4</sup>Total drift is the change with temperature without re-zeroing or re-spanning.

# B

## Equation Summary

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### General Form

The LI-840A computes CO<sub>2</sub> and H<sub>2</sub>O concentrations using an equation of the form

$$c = f(\alpha g(\alpha, P) S(\alpha)) (T + 273.15) \quad \text{B-1}$$

where  $c$  is concentration,  $f()$  is the calibration function,  $\alpha$  is the absorbance,  $g(\alpha, P)$  is the pressure correction,  $S(\alpha)$  is the span, and  $T$  is the temperature (°C) of the gas in the cell, typically 51.5 °C. Absorbance is computed from

$$\alpha = \left(1 - \frac{V}{V_o} Z\right) \quad \text{B-2}$$

where  $V$  and  $V_o$  are the raw detector sample and reference readings, and  $Z$  is the zeroing parameter.

Span is a linear function of absorbance.

$$S(\alpha) = S_0 + S_1 \alpha \quad \text{B-3}$$

### H<sub>2</sub>O Equations

Absorptance  $\alpha_w$  for water vapor is computed from

$$\alpha_w = \left(1 - \frac{V_w}{V_{wo}} Z_w\right) \quad \text{B-4}$$

where  $V_w$  and  $V_{wo}$  are the sample and reference raw detector readings and  $Z_w$  is the zero parameter. The pressure correction for water vapor is an empirical function  $g_w()$  of absorptance and pressure  $P$ :

$$g_w(\alpha_w, P) = \frac{P_o}{P\left(1+0.8\alpha_w\left(\frac{P_o}{P}-1\right)\right)} \quad \text{B-5}$$

The value of  $P_o$  is 99 kPa. When the pressure correction is not enabled,  $g_w()$  is simply 1.0. Values for  $g_w()$  can be viewed on the diagnostics screen (Section 3).

Water vapor concentration  $W$  (mmol mol<sup>-1</sup>) is computed from

$$W = f_w(\alpha_w g_w(\alpha_w, P) S_W(\alpha_w)) (T + 273 - 15) \quad \text{B-6}$$

where  $f_w(x)$  is a third order polynomial whose coefficients are given on the calibration sheet.

$$f_w(x) = a_{w1}x + a_{w2}x^2 + a_{w3}x^3 \quad \text{B-7}$$

## CO<sub>2</sub> Equations

The measurement of CO<sub>2</sub> is a bit more complicated than for H<sub>2</sub>O because of the influence of water vapor. There is a slight direct cross sensitivity in the CO<sub>2</sub> signal to H<sub>2</sub>O. This is measured at the factory and accounted for in the computation of absorbance (Equation B-8). There is also a band broadening effect that is accounted for in the computation of concentration (Equation B-12).

CO<sub>2</sub> absorbance  $\alpha_c$  is computed from

$$\alpha_c = \left( 1 - \left( \frac{V_c}{V_{co}} + X_{wc} \left( 1 - \frac{V_w}{V_{wo}} \right) \right) Z_c \right) \quad \text{B-8}$$

where  $V_c$  and  $V_{co}$  are the raw detector signals for sample and reference,  $Z_c$  is the CO<sub>2</sub> zero parameter, and  $X_{wc}$  is a cross sensitivity parameter for the effect of water vapor on CO<sub>2</sub>. Its value is reported on the calibration sheet as “XS=”.

The empirical pressure correction function  $g_c()$  depends on CO<sub>2</sub> absorbance and pressure:

When  $P = P_o$ ,  $g_c() = 1$ .

When  $P < P_o$

$$g_c(\alpha_c, P) = X$$

$$X = \frac{1}{A+B\left(\frac{1}{z-\alpha_c} - \frac{1}{z}\right)} + 1$$

$$A = \frac{1}{a(p-1)} \quad \text{B-9}$$

$$B = \frac{1}{\frac{1}{b+cp} + d}$$

$$p = \frac{P_0}{P}$$

where  $a = 1.10158$ ,  $b = -6.1217 * 10^{-3}$ ,  $c = -0.266278$ ,  $d = 3.69895$ , and  $z$  is the asymptotic value of absorbance, obtained from the calibration coefficients (see Equation B-13).

$$z = a_{c1} + a_{c3} \quad \text{B-10}$$

When  $P > P_0$

$$g_c(\alpha_c, P) = \frac{1}{X}$$

$$P = \frac{P}{P_0} \quad \text{B-11}$$

where  $X$ ,  $A$ , and  $B$  are computed as in Equation B-9. The variable  $g_c()$  is viewable on the Diagnostics screen (see "Operation" on page 3-1).

CO<sub>2</sub> concentration  $C$  ( $\mu\text{mol mol}^{-1}$ ) is computed from

$$C = f_c \left( \frac{\alpha_c g_c(\alpha_c, P)}{\psi(W)} S_c(\alpha_c) \right) \psi(W) (T + 273.15) \quad \text{B-12}$$

where  $f_c(x)$  is a function whose inverse is a double rectangular hyperbola, and whose coefficients ( $a_1 \dots a_4$ ) are given on the calibration sheet.

$$f_c^{-1}(C) = \frac{a_{c1}C}{a_{c2}+C} + \frac{a_{c3}C}{a_{c4}+C} \quad \text{B-13}$$

Solving Equation B-13 for  $C$  yields the calibration function

$$f_c(x) = \frac{(a_2 a_3 + a_1 a_4) - (a_2 + a_4)x - \sqrt{(a_2 - a_4)^2 x^2 + Dx + (a_2 a_3 + a_1 a_4)^2}}{2(x - a_1 - a_3)} \quad \text{B-14}$$

Where

$$D = 2(a_2 - a_4)(a_1 a_4 - a_2 a_3) \quad \text{B-15}$$

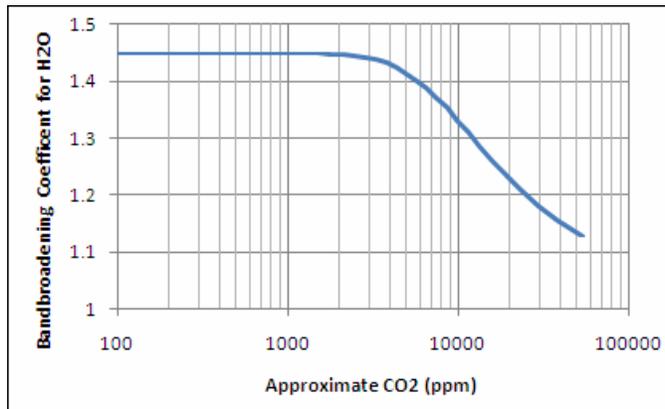
$\psi(W)$  accounts for band broadening by water vapor, and is viewable on the Diagnostic screen (Section 3).

$$\psi(W) = 1 + (h(\alpha_c) - 1) \frac{W}{1000} \quad \text{B-16}$$

The band broadening coefficient  $h(\alpha_c)$  has been determined to be 1.45 for the LI-840A for CO<sub>2</sub> concentrations near ambient. At higher concentrations, the value decreases. We capture this behavior with an empirical relationship (Equation B-17).

$$h(\alpha_c) = \frac{1}{(0.64b_w - 0.64)e^{-3\left(\frac{z}{\alpha_c} - 1\right)} + \frac{1}{b_w}}$$

Where  $z$  is from Equation B-10, and  $b_w$  is the low concentration band broadening coefficient: 1.45. This is the value shown on the calibration sheet as BB=1.45. The present value of  $h(\alpha_c)$  is viewable on the Diagnostics screen (Section 3). The typical relationship between  $h(\alpha_c)$  and CO<sub>2</sub> concentration is illustrated below. ('Typical' because the exact relationship depends on the relationship between absorbance and CO<sub>2</sub>, which is the calibration curve.)



Implementation Note: We formulated Equation B-17 with  $0.64b_w - 0.64$  instead of the simple equivalent (0.29) because this allows band broadening corrections to be turned off by setting  $b_w$  to 1.

When  $b_w = 1$ ,  $h(\alpha_c) = 1$  everywhere. Also, to avoid computational problems (underflows, overflows, and division by zero) we constrain the argument  $\alpha_c$  when computing  $h(\alpha_c)$  to be

$$0.1 < \alpha_c \leq z \tag{B-18}$$

$\alpha_c - 0.1$  is typically equivalent to about 600 ppm.

### Zeroing H<sub>2</sub>O

When the command for zeroing water is received, the LI-840A computes the water zero from Equation B-19, where  $\bar{V}_w$  and  $\bar{V}_{wo}$  are averaged for 5 seconds.

$$Z_w = \frac{\bar{V}_{wo}}{\bar{V}_w} \tag{B-19}$$

### Zeroing CO<sub>2</sub>

When the command for zeroing CO<sub>2</sub> is received, the LI-840A computes the CO<sub>2</sub> zero term from Equation B-20, where  $\bar{V}_c$ ,  $\bar{V}_{co}$ ,  $\bar{V}_w$ , and  $\bar{V}_{wo}$  are averaged for 5 seconds.

$$Z_c = \frac{1}{\left(\frac{\bar{V}_c}{\bar{V}_{co}} + X_{wc} \left(1 - \frac{\bar{V}_w}{\bar{V}_{wo}} Z_w\right)\right)} \tag{B-20}$$

### Spanning H<sub>2</sub>O

When the command for setting the span for H<sub>2</sub>O is received, along with the target concentration  $W_T$ , the LI-840A computes  $S_{w0}$  from Equation B-21, where  $\bar{\alpha}_w$  is averaged over five seconds.

$$S_{w0} = \frac{\beta_w}{\bar{\alpha}_w} - S_{w1} \bar{\alpha}_w \quad \text{B-21}$$

where

$$\beta_w = \frac{f_w^{-1}\left(\frac{w_T}{T+273.15}\right)}{g_w(\bar{\alpha}_w, P)} \quad \text{B-22}$$

The instrument retains the following values, which are used for subsequent secondary spans:

$$\alpha_{w1} = \bar{\alpha}_w \quad \text{B-23}$$

$$\beta_{w1} = \beta_w \quad \text{B-24}$$

### Secondary Span H<sub>2</sub>O

When the secondary span command for H<sub>2</sub>O is received, the instrument computes new values for both  $S_{w0}$  and  $S_{w1}$ . First, it measures a new  $\bar{\alpha}_w$  and computes a new  $\beta_w$  from Equation B-22. Then, it uses these plus the retained values ( $\alpha_{w1}$  and  $\beta_{w1}$  from the previous normal span) to compute

$$S_{w1} = \frac{\frac{\beta_w}{\bar{\alpha}_w} - \frac{\beta_{w1}}{\alpha_{w1}}}{\bar{\alpha}_w - \alpha_{w1}} \quad \text{B-25}$$

Given the new span slope  $S_{w1}$ , update the span offset  $S_{w0}$  by Equation B-21.

## Spanning CO<sub>2</sub>

When the command for setting the span for CO<sub>2</sub> is received, along with the target concentration  $C_T$ , the LI-840A computes  $S_{c0}$  from Equation B-26, where  $\bar{\alpha}_c$  and  $\bar{W}$  are averaged for 5 seconds.

$$S_{c0} = \frac{\beta_c}{\bar{\alpha}_c} - S_{c1} \bar{\alpha}_c \quad \text{B-26}$$

where

$$\beta_c = \frac{f_c^{-1} \left( \frac{C_T}{(T+273.15)\psi(\bar{W})} \right) \psi(\bar{W})}{g_c(\bar{\alpha}_c, P)} \quad \text{B-27}$$

Note that

$$\begin{aligned} \psi(\bar{W}) &= 1 + (h(\bar{\alpha}_c) - 1) \frac{\bar{W}}{1000} \\ &= \left( 1 + \left( \frac{1}{(0.64b_w + 0.64)e^{-3\left(\frac{z}{\bar{\alpha}_e} - 1\right)} + \frac{1}{b_w}} \right) \frac{\bar{W}}{1000} \right) \end{aligned} \quad \text{B-28}$$

The instrument retains the following values which are used for subsequent secondary spans, if necessary:

$$\alpha_{c1} = \bar{\alpha}_c \quad \text{B-29}$$

$$\beta_{c1} = \beta_c$$

B-30

### Secondary Span CO<sub>2</sub>

When the secondary span command for CO<sub>2</sub> is received, the instrument computes new values for both  $S_{c0}$  and  $S_{c1}$ . First, it measures a new  $\bar{\alpha}_c$  and computes a new  $\beta_c$  from Equation B-27. Then it uses these, plus the retained values ( $\alpha_{c1}$  and  $\beta_{c1}$  from the previous normal span) to compute

$$S_{c1} = \frac{\frac{\beta_c}{\bar{\alpha}_c} - \frac{\beta_{c1}}{\alpha_{c1}}}{\bar{\alpha}_c - \alpha_{c1}} \quad \text{B-31}$$

Given the new span slope  $S_{c1}$ , update the span offset  $S_{c0}$  by Equation B-26.

## Symbol Summary

Many of the quantities described in the above section are available from the LI-840A. These are summarized in Table B-1 below.

**Table B-1.** Symbol summary

Symbol	XML Tag: <LI840>+	Description
$\alpha_w$	<data><h2oabs>	H <sub>2</sub> O absorbance
$g_w(\alpha_w, P)$	<AUXdata><pHA>	Pressure corrected absorbance of H <sub>2</sub> O
W	<data><h2o>	H <sub>2</sub> O (mmol mol <sup>-1</sup> )
P	<data><cellpress>	Pressure (kPa)
T	<data><celltemp>	Temp (C)

Table B-1. Symbol summary (...continued)

Symbol	XML Tag: <LI840>+	Description
$\alpha_c$	<data><co2abs>	CO <sub>2</sub> absorptance
$g_c(\alpha_c, P)$	<AUXdata><pcA>	Pressure corrected absorptance of CO <sub>2</sub>
C	<data><co2>	CO <sub>2</sub> ( $\mu\text{mol mol}^{-1}$ )
$V_w$	<data><raw><h2o>	Raw detector readings
$V_{w0}$	<data><raw><h2oref>	
$V_c$	<data><raw><co2>	
$V_{c0}$	<data><raw><co2ref>	
$a_{w1} \dots a_{w3}$	<poly><h2o>	Calibration coefficients
$a_{c1} \dots a_{c4}$	<poly><co2>	Calibration coefficients
$Z_w$	<cal><h2okzero>	
$S_{w0}$	<cal><h2okspan>	
$S_{w1}$	<cal><h2okspan2>	
$Z_c$	<cal><co2kzero>	Zero and Span values
$S_{c0}$	<cal><co2kspan>	
$S_{c1}$	<cal><co2kspan2>	
$x_{wc}$	<poly><xs>	Cross sensitivity coefficient
$b_w$	<poly><bb>	Band broadening coefficient for low CO <sub>2</sub>
$h(\alpha_c)$	<AUXdata><bb_EFF>	Computed band broadening coeff for the current absorptance
$\psi(W)$	<AUXdata><psi>	Band broadening correction factor for water vapor

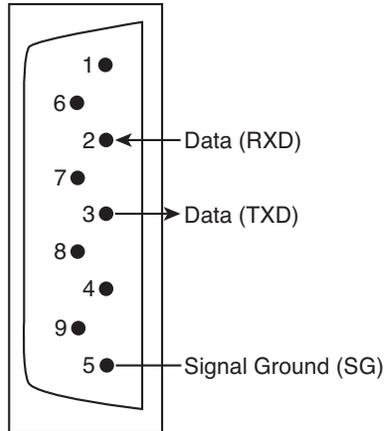


# C

## Pin Assignments

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### DB-9 Connector





# D

## Suppliers

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Although the LI-840A has no internal chemicals to replace, the following suppliers may be useful for obtaining chemicals for generating a chemical zero gas. The company names, addresses, and phone numbers are the most current we have at the time of this printing. In some cases the information may change without notice.

### Soda Lime (6-12 mesh) and Magnesium Perchlorate (Anhydrous) $\text{Mg}(\text{ClO}_4)_2$

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#### GFS Chemicals

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www.gfschemicals.com  
P.O. Box 245  
Powell, OH 43065  
Phone: 614-881-5501  
FAX: 614-881-5989  
Toll free: 800-858-9682

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**Soda Lime:** Part #66352  
 **$\text{Mg}(\text{ClO}_4)_2$ :** Part #49001 (500g, <8% water)

## Appendix D

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### Fisher Scientific

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www.fishersci.com  
711 Forbes Avenue  
Pittsburgh, PA 15219-4785  
Phone: 201-467-6400  
FAX: 201-379-7415  
Toll free: 800-776-7000  
Toll free FAX: 800-926-1166

---

**Soda Lime:** Part #S201-212  
(LI-COR Part #9960-071)  
**Mg(ClO<sub>4</sub>)<sub>2</sub>:** Part #M54-500 (500g)

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### Thomas Scientific

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www.thomassci.com  
P.O. Box 99  
Swedesboro, NJ 08085-6099  
Phone: 609-467-2000  
FAX: 609-467-3087  
Toll free: 800-345-2100  
Toll free FAX: 800-345-5232

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**Soda Lime:** Part #C703-B76  
**Mg(ClO<sub>4</sub>)<sub>2</sub>:** Part #C260-M61 (Dehydrite, 500g)

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**Ascarite II**

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**GFS Chemicals**

www.gfschemicals.com  
P.O. Box 245  
Powell, OH 3065  
Phone: 614-881-5501  
FAX: 614-881-5989  
Toll free: 800-858-9682

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**Thomas Scientific**

www.thomassci.com  
P.O. Box 99  
Swedesboro, NJ 08085-6099  
Phone: 609-467-2000  
FAX: 609-467-3087  
Toll free: 800-345-2100  
Toll free FAX: 800-345-5232

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**P.W. Perkins Co., Inc.**

www.pwperkins.com  
856-769-3525

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**Fisher Scientific**

www.fishersci.com  
711Forbes Avenue  
Pittsburgh, PA 15219-4785  
Phone: 201-467-6400  
FAX: 201-379-7415  
Toll free: 800-776-7000  
Toll free FAX: 800-926-1166

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## Appendix D

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### Electronic Relay Switches

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**Crydom Inc.**

9525 Chesapeake Dr.  
San Diego, CA 92123  
800-827-9366  
FAX: 619-715-7280

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**Potter & Brumfield Products Div.**

Siemens Electromechanical Components, Inc.  
200 S. Richland Creek Dr.  
Princeton, IN 47671-0001  
info@ae.sec.siemens.com

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# E

## Configuration Grammar

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### Introduction

The LI-840A communicates exclusively through a serial interface. The following discussion describes how to implement a synchronized communication protocol.

### LI-840A Communications and XML

The configuration grammar used to communicate with the LI-840A is based upon a subset of the eXtensible Markup Language (XML). XML relies on the use of tags to "Markup", or give structural rules to a set of data.

A tag is a descriptive identifier, enclosed between a less than (<) and a greater than (>) symbol, used in part to describe a piece of data. For example, <NAME> is a tag that describes a person's name. Each tag must have a corresponding end tag, denoted by '/'. Extending the example above, the end tag of <NAME> is </NAME>.

Elements are the basic unit of XML content. An element consists of a start tag and an end tag, and everything in between. For example, consider the following element:

```
<NAME>George</NAME>.
```

In this example, `<NAME>` (start tag) and `</NAME>` (end tag) comprise the markup, and "George" comprises the data. Because XML is extensible, tags can be defined specifically for the data they are meant to describe.

Elements can also contain other elements other than data.

```
<NAME>
  <FIRST>George</FIRST>
  <LAST>Smith</LAST>
</NAME>
```

In this example, the outermost element `<NAME>` encompasses two other elements that contain data. All elements combined make up the XML document.

---

## Connecting and Configuring Data Output

The LI-840A communicates through a serial port on the front of the instrument. This port is configured as follows:

Baud Rate: 9600 bps

Data Bits: 8

Parity: None

Stop Bits: 1

Flow Control: None

After a serial connection is established, the LI-840A will immediately send data out the serial port in the manner in which it was configured previously. In order to reconfigure the LI-840A to output specific data values, you must send the RS-232 portion of the XML grammar to the instrument with the desired values "turned on". To "turn on" the data value, set the value of the element to TRUE. As an example, the following string is sent to the instrument after a connection has been made between the computer (using the Windows® application software) and the LI-840A:

```
<LI840>
  <CFG>
    <OUTRATE>1</OUTRATE>
  </CFG>
  <RS232>
    <STRIP>FALSE</STRIP>
    <ECHO>FALSE</ECHO>
    <CELL_TEMP>TRUE</CELL_TEMP>
    <CO2>TRUE</CO2>
```

```
<CO2ABS>FALSE</CO2ABS>
<CELLPRES>TRUE</CELLPRES>
<IVOLT>TRUE</IVOLT>
</RS232>
</LI840>
```

### Sending Data to the LI-840A

To send data to the LI-840A, each string must end with a '\n' to ensure that the LI-840A can parse consecutive commands.

After data have been sent to the LI-840A, the instrument replies with:

```
<LI840><ACK>TRUE</ACK></LI840>
```

if the XML was received and parsed correctly. If there was an error in the XML, the following is sent:

```
<LI840><ACK>FALSE</ACK></LI840>.
```

For example, suppose that you would like to reconfigure the LI-840A to stop outputting cell temperature. Here is the command to send to the LI-840A:

```
<LI840><RS232><CELLTEMP>FALSE</CELLTEMP></RS232></LI840>
```

If the command was received correctly, the LI-840A replies with

---

```
<LI840><ACK>TRUE</ACK></LI840>.
```

## Reading Data From the LI-840A

The LI-840A can send data continuously. To determine where one message ends and the next begins, each XML document sent from the LI-840A is delimited with a '\n' (0x10) character.

## Polling the Current State of the LI-840A

The LI-840A can be polled for individual sets of data by sending an XML document with a '?' in place of the set of elements requested. The element sets that can be requested include the data set, the current configuration, and the entire state of the instrument.

Sending this command:

```
<LI840><DATA>?</DATA></LI840>
```

instructs the LI-840A to send the most recent set of data values (as configured) as an XML document.

Sending this command:

```
<LI840><CFG>?</CFG></LI840>
```

instructs the LI-840A to send an XML document containing all of the configuration information, including heater status, filter settings, DACs, and alarms.

To receive the entire state of the instrument as an XML document, send this command:

```
<LI840>?</LI840>.
```

## Calibration

The LI-840A CO<sub>2</sub> calibration (zero and span) can be performed using XML grammar. This is accomplished in three steps:

1. Send the calibration command to the LI-840A.

```
<LI840>
  <CAL>
    <DATE>{iso date}</DATE>
    <CO2SPAN>{int}</CO2SPAN>
    <CO2SPAN2>{int}</CO2SPAN2>
    <CO2KZERO>{bool}</CO2KZERO>
    <co2kspan>{float}</co2Kspan>
    <co2kspan2>{float}</co2Kspan2>
  </CAL>
</LI840>
```

2. An acknowledgement is returned from the LI-840A if the command was accepted.

```
<LI840><ACK>TRUE</ACK></LI840>
```

3. After a few seconds, all of the calibration information is returned from the LI-840A, indicating that it has finished the zero and/or span.

```
<LI840>
  <CAL>
    <CO2LASTZERO>{iso date}</CO2LASTZERO>
    <CO2KZERO>{float}</CO2KZERO>
    <CO2LASTSPAN>{iso date}</CO2LASTSPAN>
    <CO2LASTSPAN2>{iso date}</CO2LASTSPAN2>
    <CO2KSPAN>{float}</CO2KSPAN>
    <CO2KSPAN2>{float}</CO2KSPAN2>
  </CAL>
</LI840>
```

If the calibration cannot be performed, an ERROR is sent:

```
<LI840><ERROR>{Error Text}</ERROR></LI840>.
```

## To Zero the LI-840A

1. Send the XML command to initiate the zero.

```
<LI840>
  <CAL>
    <DATE>YYYY-MM-DD</DATE>
    <CO2ZERO>TRUE</CO2ZERO>
  </CAL>
</LI840>
```

2. Wait for the acknowledgement.
3. Wait for the date to be returned to verify the zero operation succeeded. If the operation fails an <ERROR> will be sent.

### To Span the LI-840A

1. Send the XML command to initiate the span.

```
<LI840>  
  <CAL>  
    <DATE>YYYY-MM-DD</DATE>  
    <CO2SPAN>Gas Concentration</CO2SPAN>  
  </CAL>  
</LI840>
```

2. Wait for the acknowledgement.
3. Wait for the date to be returned to verify the span operation succeeded. If the operation fails an <ERROR> will be sent.

### To Perform a Two Point Span

1. Send the XML command to initiate the first span.

```
<LI840>  
  <CAL>  
    <DATE>YYYY-MM-DD</DATE>
```

```

        <CO2SPAN>Gas Concentration</CO2SPAN>
    </CAL>
</LI840>

```

- 2.** Wait for the acknowledgement.
- 3.** Wait for the date to be returned to verify the span operation succeeded. If the operation fails an <ERROR> will be sent.

- 4.** Send the XML command to initiate the second span.

```

<LI840>
    <CAL>
        <DATE>YYYY-MM-DD</DATE>
        <CO2SPAN2>Gas Concentration</CO2SPAN2>
    </CAL>
</LI840>

```

- 5.** Wait for the acknowledgment.
- 6.** Wait for the date to be returned to verify the span operation succeeded. If the operation fails an <ERROR> will be sent.

### LI-840A XML Grammar and Element Description

#### Data Types in the XML Grammar

{val | val |...}

The value will be a member of the specified set. | = or.

{bool}

Boolean values, TRUE | FALSE.

{float}

Floating point values in decimal or exponential notation.

{int}

Integers.

{iso date}

A date in the ISO format. 4 digit year - 2 digit month - 2 digit day.

Example: 2002-04-27.

#### XML Grammar

```
<LI840>
  <ACK>{bool}</ACK>
  <VER>{string}</VER>
  <DATA>
    <CELLTEMP>{float}</CELLTEMP>
    <CELLPRES>{float}</CELLPRES>
    <CO2>{float}</CO2>
    <CO2ABS>{float}</CO2ABS>
    <H2O>{float}</H2O>
    <H2OABS>{float}</H2OABS>
```

```
<H2ODEWPOINT>{float}</H2ODEWPOINT>
<IVOLT>{float}</IVOLT>
<RAW>
  <CO2>{int}</CO2>
  <CO2REF>{int}</CO2REF>
  <H2O>{int}</H2O>
  <H2OREF>{int}</H2OREF>
</RAW>
</DATA>
<AUXDATA>
  <PCA>{float}</PCA>
  <PHA>{float}</PHA>
  <BB_EFF>{float}</BB_EFF>
  <PSI>{float}</PSI>
</AUXDATA>
<RS232>
  <CO2>{bool}</CO2>
  <H2O>{float}</H2O>
  <CELLTEMP>{bool}</CELLTEMP>
  <CELLPRES>{bool}</CELLPRES>
  <IVOLT>{bool}</IVOLT>
  <CO2ABS>{bool}</CO2ABS>
  <H2OABS>{bool}</H2OABS>
  <H2ODEWPOINT>{bool}</H2ODEWPOINT>
  <RAW>
    <CO2>{bool}</CO2>
    <CO2REF>{bool}</CO2REF>
    <H2O>{bool}</H2O>
    <H2OREF>{bool}</H2OREF>
```

```
</RAW>
<ECHO>{bool}</ECHO>
<STRIP>{bool}</STRIP>
</RS232>
<CFG>
  <HEATER>{bool}</HEATER>
  <PCOMP>{bool}</PCOMP>
  <FILTER>{int}</FILTER>
  <OUTRATE>{float}</OUTRATE>
  <ALARMS>
    <SOURCE>H2O | CO2</SOURCE>
    <ENABLED>{bool}</ENABLED>
    <HIGH>{float}</HIGH>
    <HDEAD>{float}</HDEAD>
    <LOW>{float}</LOW>
    <LDEAD>{float}</LDEAD>
  </ALARMS>
  <BENCH>{5|14}</BENCH>
  <SPAN>{int}</SPAN>
  <DACS>
    <RANGE>{2.5|5.0}</RANGE>
    <SET1>{float}</SET1>
    <SET2>{float}</SET2>
    <D1>{NONE|CO2|H2O|H2ODP|CELLTEMP|CELLPRES}</D1>
    <D1_0>{float}</D1_0>
    <D1_F>{float}</D1_F>
    <D2>{NONE|CO2|H2O|H2ODP|CELLTEMP|CELLPRES}</D2>
    <D2_0>{float}</D2_0>
    <D2_F>{float}</D2_F>
```

```
</DACS>
</CFG>
<CAL>
  <DATE>{serial number and iso date}</DATE>
  <CO2ZERO>{bool}</CO2ZERO>
  <CO2SPAN>{int}</CO2SPAN>
  <co2span2>{int}</co2span2>
  <H2OZERO>{bool}</H2OZERO>
  <H2OSPAN>{int}</H2OSPAN>
  <H2OSPAN2>{int}</H2OSPAN2>
  <CO2KZERO>{float}</CO2KZERO>
  <CO2KSPAN>{float}</CO2KSPAN>
  <co2kspan2>{float}</co2span2>
  <H2OZERO>{float}</H2OZERO>
  <H2OKSPAN>{float}</H2OKSPAN>
  <h2okspan2>{float}</h2ospan2>

  or

  <CO2LASTZERO>{iso date}</CO2LASTZERO>
  <CO2LASTSPAN>{iso date}</CO2LASTSPAN>
  <H2OLASTZERO>{iso date}</H2OLASTZERO>
  <H2OLASTSPAN>{iso date}</H2OLASTSPAN>
</CAL>
<POLY>
  <DATE>{string}</DATE>
  <BB>{float}</BB>
  <XS>{float}</XS>
  <RESET>{bool}</RESET>
```

```
<CO2>
  <A1>{float}</A1>
  <A2>{float}</A2>
  <A3>{float}</A3>
  <A4>{float}</A4>
</CO2>
<H2O>
  <A1>{float}</A1>
  <A2>{float}</A2>
  <A3>{float}</A3>
</H2O>
<PRESS>
  <A0>{float}</A0>
  <A1>{float}</A1>
</PRESS>
</POLY>
<ERROR>{string}</ERROR>
</LI840>
```

---

<b>Tag</b>	<b>Parent</b>	<b>Value(s)</b>	<b>R/W</b>	<b>Comments</b>
<LI840>	N/A (root)	<ACK> <VER> <ERROR> <DATA> <AUXDATA> <RS232> <CFG> <CAL> <POLY> ?		<LI840> is the root tag for all XML statements. A ? outputs the entire XML document.

---

**Examples:**

```
<LI840>?</LI840>
<LI840><ACK>TRUE</ACK></LI840>
```

Tag	Parent	Value(s)	R/W	Comments
<DATA>	<LI840>	<CO2> <CO2ABS> <H2O> <H2ODEWPOINT> <H2OABS> <CELLTEMP> <CELLPRES> <IVOLT> <RAW> ?		<DATA> contains all data values sent from the LI-840A. All of the elements within the DATA tag are readable only. A ? requests all data values to be output.

Examples:

```
<LI840><DATA><CO2>2.34e2</CO2><IVOLT>1.5e2</IVOLT></DATA></LI840>  
<LI840><DATA>?</DATA></LI840>
```

Tag	Parent	Value(s)	R/W	Comments
<CO2>	<DATA>	Float	R	CO <sub>2</sub> in ppm
<CO2ABS>	<DATA>	Float	R	CO <sub>2</sub> absorption
<H <sub>2</sub> O>	<DATA>	Float	R	H <sub>2</sub> O in mmol/mol
<H2ODEWPOINT>	<DATA>	Float	R	H <sub>2</sub> O in °C
<H2OABS>	<DATA>	Float	R	H <sub>2</sub> O absorption
<CELLTEMP>	<DATA>	Float	R	Cell temperature
<CELLPRES>	<DATA>	Float	R	Cell pressure
<IVOLT>	<DATA>	Float	R	Input voltage
<RAW>	<DATA>	<CO2> <CO2REF> <H2O> <H2OREF>		Raw detector readings

Examples:

```
<LI840><DATA><CELLTEMP>5.16E1</CELLTEMP><CELLPRES>9.742E1</CELLPRES>
<CO2>6.17E2</CO2><CO2ABS>8.94E2</CO2ABS>DATA</LI840>
```

## Appendix E

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Tag	Parent	Value(s)	R/W	Comments
<CO2>	<RAW>	Integer	R	
<CO2REF>	<RAW>	Integer	R	
<H2O>	<RAW>	Integer	R	
<H2OREF>	<RAW>	Integer	R	

Tag	Parent	Value(s)	R/W	Comments
<AUXDATA>	<LI840>	?		<AUXDATA> contains all auxiliary data values that can be retrieved from the LI-840A. All of the elements within the AUXDATA tag are readable only. A ? requests all data values to be output.

<b>Tag</b>	<b>Parent</b>	<b>Value(s)</b>	<b>R/W</b>	<b>Comments</b>
<PCA>	<AUXDATA>	Float	R	
<PHA>	<AUXDATA>	Float	R	
<PSI>	<AUXDATA>	Float	R	
<BB_EFF>	<AUXDATA>	Float	R	

<b>Tag</b>	<b>Parent</b>	<b>Value(s)</b>	<b>R/W</b>	<b>Comments</b>
<RS232>	<LI840>	<CO2> <CO2ABS> <H2O><H2ODEWPOINT> <H2OABS> <CELLTEMP> <CELLPRES> <IVOLT> <RAW> <ECHO> <STRIP>		Setting <RS232> values will determine what values are output in <DATA>

Tag	Parent	Value(s)	R/W	Comments
<CO2>	<RS232>	TRUE   FALSE	R/W	CO <sub>2</sub> in ppm
<CO2ABS>	<RS232>	TRUE   FALSE	R/W	CO <sub>2</sub> absorption
<H2O>	<RS232>	TRUE   FALSE	R/W	H <sub>2</sub> O in mmol/mol
<H2ODEWPOINT>	<RS232>	TRUE   FALSE	R/W	H <sub>2</sub> O dew point
<H2OABS>	<RS232>	TRUE   FALSE	R/W	H <sub>2</sub> O absorption
<CELLTEMP>	<RS232>	TRUE   FALSE	R/W	Cell temperature
<CELLPRES>	<RS232>	TRUE   FALSE	R/W	Cell pressure
<IVOLT>	<RS232>	TRUE   FALSE	R/W	Input voltage
<RAW>	<RS232>	<CO2> <CO2REF> <H2O> <H2OREF>		Raw detector readings
<ECHO>	<RS232>	TRUE   FALSE	R/W	Echo commands sent to LI-840
<STRIP>	<RS232>	TRUE   FALSE	R/W	Strip XML from all data sent

Example:

```
<LI840><CFG><OUTRATE>0.5</OUTRATE></CFG><RS232><STRIP>FALSE</STRIP>
<ECHO>FALSE</ECHO><CELLTEMP>TRUE</CELLTEMP><CO2ABS>TRUE</CO2ABS>
<CO2>TRUE</CO2><CELLPRES>TRUE</CELLPRES><IVOLT>TRUE</IVOLT><RAW>TRUE
</RAW></RS232></LI840>
```

<b>Tag</b>	<b>Parent</b>	<b>Value(s)</b>	<b>R/W</b>	<b>Comments</b>
<CO2>	<RAW>	Integer	R	
<CO2REF>	<RAW>	Integer	R	
<H2O>	<RAW>	Integer	R	
<H2OREF>	<RAW>	Integer	R	

## Appendix E

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Tag	Parent	Value(s)	R/W	Comments
<CFG>	<LI840>	<OUTRATE> <HEATER> <PCOMP> <DOFFSET> <FILTER> <ALARMS> <DACS> <BENCH> <SPAN> ?		Elements within the <CFG> tag control system settings.

Example:

```
<LI840><CFG><HEATER>TRUE</HEATER><PCOMP>TRUE</PCOMP></CFG></LI840>
```

<b>Tag</b>	<b>Parent</b>	<b>Value(s)</b>	<b>R/W</b>	<b>Comments</b>
<OUTRATE>	<CFG>	0.5 to 20	R/W	Output data every N seconds (0.5 s increments).
<HEATER>	<CFG>	TRUE   FALSE	R/W	Turn heater on/off.
<PCOMP>	<CFG>	TRUE   FALSE	R/W	Pressure compensation on/off.
<FILTER>	<CFG>	0 to 20	R/W	Set a 0 to 20 second filter.
<ALARMS>	<CFG>	<SOURCE> <ENABLED> <HIGH> <HDEAD> <LOW> <LDEAD>		High and low alarm settings.
<DACS>	<CFG>	<RANGE> <SET1> <SET2> <D1> <D1_0> <D1_F> <D2> <D2_0> <D2_F>		DAC outputs.
<BENCH>	<CFG>	14	R	Optical bench length (cm).

## Appendix E

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Tag	Parent	Value(s)	R/W	Comments
<ENABLED>	<ALARMS>	TRUE   FALSE	R/W	Enable alarms.
<SOURCE>	<ALARMS>	CO2   H2O	R/W	Channel (CO <sub>2</sub> :ppm, H <sub>2</sub> O:mmol/mol)
<HIGH>	<ALARMS>	Float	R/W	High alarm on at this value.
<HDEAD>	<ALARMS>	Float	R/W	High alarm off at this value.
<LOW>	<ALARMS>	Float	R/W	Low alarm on at this value.
<LDEAD>		Float	R/W	Low alarm off at this value.

### Example:

```
<LI840><CFG><ALARMS><ENABLED>TRUE</ENABLED><SOURCE>H2O</SOURCE>  
<HIGH>1600</HIGH><HDEAD>1500</HDEAD><LOW>200</LOW><LDEAD>300</LDEAD>  
</ALARMS></CFG></LI840>
```

<b>Tag</b>	<b>Parent</b>	<b>Value(s)</b>	<b>R/W</b>	<b>Comments</b>
<RANGE>	<DACS>	2.5   5.0	R/W	Output voltage. 2.5V or 5.0V.
<SET1>	<DACS>	Float	R/W	Set DAC output to value (DACS must be NONE)
<SET2>	<DACS>	Float	R/W	Set DAC output to value (DACS must be NONE)
<D1>	<DACS>	CO2   H2O   H2ODEWPOINT   CELLPRES   CELLTEMP   NONE	R/W	DAC1
<D1_0>	<DACS>	Float	R/W	Value where DAC1 outputs 0V
<D1_F>	<DACS>	Float	R/W	Value where DAC1 outputs full scale
<D2>	<DACS>	CO2   H2O   H2ODEWPOINT   CELLPRES   CELLTEMP   NONE	R/W	DAC2
<D2_0>	<DACS>	Float	R/W	Value where DAC2 outputs 0V
<D2_F>	<DACS>	Float	R/W	Value where DAC2 outputs full scale

Example:

```
<LI840><CFG><DACS><RANGE>2.5</RANGE><D1>CO2</D1><D2>CELLTEMP</D2></DACS>
</CFG></LI840>
```

## Appendix E

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Tag	Parent	Value(s)	R/W	Comments
<CAL>	<LI840>	<DATE> <H2OZERO> <H2OSPAN> <H2OSPAN2> <H2OLASTZERO> <H2OLASTSPAN> <H2OLASTSPAN2> <H2OKZERO> <H2OKSPAN> <H2OKSPAN2> <CO2ZERO> <CO2SPAN> <CO2SPAN2> <CO2LASTZERO> <CO2LASTSPAN> <CO2LASTSPAN2> <CO2KZERO> <CO2KSPAN> <CO2KSPAN2> <POLY>		Calibration parameters. When calibrating, <DATE> must be paired with a <CO2ZERO> or a <CO2SPAN>, or a <H2OZERO> or <H2OSPAN>.

---

<b>Tag</b>	<b>Parent</b>	<b>Value(s)</b>	<b>R/W</b>	<b>Comments</b>
<DATE>	<CAL>	20 character date	W	The date the calibration is taking place.
<H2OZERO>	<CAL>	TRUE   FALSE	W	Start H <sub>2</sub> O zero.
<H2OSPAN>	<CAL>	Float (H <sub>2</sub> O °C)	W	Start the first H <sub>2</sub> O span.
<H2OSPAN2>	<CAL>	Float (H <sub>2</sub> O °C)	W	Start the second H <sub>2</sub> O span.
<H2OLASTZERO>	<CAL>	20 character date	R	Date the LI-840A was last zeroed.
<H2OLASTSPAN>	<CAL>	20 character date	R	Date the LI-840A was last spanned.
<H2OKZERO>	<CAL>	Float	R/W	Calibration constant.
<H2OKSPAN>	<CAL>	Float	R/W	Calibration constant.
<H2OKSPAN2>	<CAL>	Float	R/W	Calibration constant.
<CO2ZERO>	<CAL>	TRUE   FALSE	W	Start a CO <sub>2</sub> zero.
<CO2SPAN>	<CAL>	Float (CO <sub>2</sub> ppm)	W	Start the first CO <sub>2</sub> span.
<CO2SPAN2>	<CAL>	Float (CO <sub>2</sub> ppm)	W	Start the second CO <sub>2</sub> span.
<CO2LASTZERO>	<CAL>	20 character date	R	The date the LI-840A was last zeroed.
<CO2LASTSPAN>	<CAL>	20 character date	R	The date the LI-840A was last spanned.
<CO2KZERO>	<CAL>	Float	R/W	Calibration constant.
<CO2KSPAN>	<CAL>	Float	R/W	Calibration constant.
<CO2KSPAN2>	<CAL>	Float	R/W	Calibration constant.

## Appendix E

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Tag	Parent	Value(s)	R/W	Comments
<POLY>	<LI840>	<LI840>	R/W	Serial number and factory calibration date: HGA_XXXX Day Month Year
		<BB>	R/W	Band broadening.
		<XS>	R/W	Cross sensitivity.
		<CO2>	R/W	CO <sub>2</sub> coefficients.
		<H2O>	R/W	H <sub>2</sub> O coefficients.
		<PRESS>	R/W	Pressure correction coefficients

---

### Examples:

#### To Zero:

```
<LI840><CAL><DATE>2015-02-07</DATE><CO2ZERO>TRUE</CO2ZERO></CAL></LI840>
```

#### To Span:

```
<LI840><CAL><DATE>2015-02-07</DATE><CO2SPAN>1000</CO2SPAN></CAL></LI840>
```

#### Possible LI-840 Replies:

```
<LI840><ACK>TRUE</ACK></LI840>
```

```
<LI840><ERROR>{ErrorText}</ERROR></LI840>
```

```
<LI840><CAL><CO2LASTSPAN>{isodate}</CO2LASTSPAN><CO2LASTZERO>{isodate}</CO2LASTZERO><CO2KZERO>{float}</CO2KZERO><CO2KSPAN>{float}</CO2KSPAN></CAL></LI840>
```

<b>Tag</b>	<b>Parent</b>	<b>Value(s)</b>	<b>R/W</b>	<b>Comments</b>
<LI840>	<POLY>	20 character date	R/W	Serial number and factory calibration date:HGA XXXX Day Month Year
<BB>	<POLY>	Float	R/W	Band broadening value.
<XS>	<POLY>	Float	R/W	Cross sensitivity value.
<CO2>	<POLY>	<A1><A2><A3><A4>	R/W	Floating point coefficients for the CO <sub>2</sub> calibration inverse rectangular hyperbola.
<H2O>	<POLY>	<A1><A2><A3>	R/W	Floating point coefficients for the H <sub>2</sub> O calibration polynomial.
<PRESS>	<POLY>	<A0>	R/W	Floating point coefficient for CO <sub>2</sub> pressure correction
				<A1>

<b>Tag</b>	<b>Parent</b>	<b>Value(s)</b>	<b>R/W</b>	<b>Comments</b>
<ACK>	<LI840>	TRUE   FALSE	R	Acknowledgement to a send command.
<VER>	<LI840>	Text	R	Embedded software version.
<ERROR>	<LI840>	Text	R	Error. Includes a message.



# Warranty

Each LI-COR, inc. instrument is warranted by LI-COR, inc. to be free from defects in material and workmanship; however, LI-COR, inc.'s sole obligation under this warranty shall be to repair or replace any part of the instrument which LI-COR, inc.'s examination discloses to have been defective in material or workmanship without charge and only under the following conditions, which are:

1. The defects are called to the attention of LI-COR, inc. in Lincoln, Nebraska, in writing within one year after the shipping date of the instrument.
2. The instrument has not been maintained, repaired, or altered by anyone who was not approved by LI-COR, inc.
3. The instrument was used in the normal, proper, and ordinary manner and has not been abused, altered, misused, neglected, involved in and accident or damaged by act of God or other casualty.
4. The purchaser, whether it is a DISTRIBUTOR or direct customer of LI-COR or a DISTRIBUTOR'S customer, packs and ships or delivers the instrument to LI-COR, inc. at LI-COR inc.'s factory in Lincoln, Nebraska, U.S.A. within 30 days after LI-COR, inc. has received written notice of the defect. Unless other arrangements have been made in writing, transportation to LI-COR, inc. (by air unless otherwise authorized by LI-COR, inc.) is at customer expense.

5. No-charge repair parts may be sent at LI-COR, inc.'s sole discretion to the purchaser for installation by purchaser.

6. LI-COR, inc.'s liability is limited to repair or replace any part of the instrument without charge if LI-COR, inc.'s examination disclosed that part to have been defective in material or workmanship.

There are no warranties, express or implied, including but not limited to any implied warranty of merchantability of fitness for a particular purpose on underwater cables or on expendables such as batteries, lamps, thermocouples and calibrations.

Other than the obligation of LI-COR, inc. expressly set forth herein, LI-COR, inc. disclaims all warranties of merchantability or fitness for a particular purpose. The foregoing constitutes LI-COR, inc.'s sole obligation and liability with respect to damages resulting from the use or performance of the instrument and in no event shall LI-COR, inc. or its representatives be liable for damages beyond the price paid for the instrument, or for direct, incidental or consequential damages.

The laws of some locations may not allow the exclusion or limitation on implied warranties or on incidental or consequential damages, so the limitations herein may not apply directly. This warranty gives you specific legal rights, and you may already have other rights which vary from state to state. All warranties that apply, whether included by this contract or by law, are limited to the time period of this warranty which is a twelve-month period commencing from the date the instrument is shipped to a user who is a customer or eighteen months from the date of shipment to LI-COR, inc.'s authorized distributor, whichever is earlier.

This warranty supersedes all warranties for products purchased prior to June 1, 1984, unless this warranty is later superseded.

DISTRIBUTOR or the DISTRIBUTOR'S customers may ship the instruments directly to LI-COR if they are unable to repair the instrument themselves even though the DISTRIBUTOR has been approved for making such repairs and has agreed with the customer to make such repairs as covered by this limited warranty.

Further information concerning this warranty may be obtained by writing or telephoning Warranty manager at LI-COR, inc.





# Measuring Change in a Changing World<sup>®</sup>

***LI-COR***<sup>®</sup>

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